Can postoperative length of stay or discharge within five days of first time isolated coronary artery bypass graft surgery be predicted from preoperative patient variables?

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DECLARATION

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ABSTRACT

In recent years there has been a steady increase in the number of patients being discharged within five days of coronary artery bypass graft surgery. The ability to be able to predict those patients likely to be discharged within five days of surgery is important to improve the individual patient pathway, plan resources and surgical activity, and also to achieve current policy objectives.

Guided by the theory of Stress, Appraisal and Coping (Lazarus and Folkman, 1984), the aim of this observational study was to develop and validate local multivariate models from preoperative patient variables for the purpose of predicting postoperative length of stay and discharge within five days of surgery. The study also investigated the influence of previously neglected psychological variables on these outcomes.

The study was conducted in two phases:

Phase I

A cross-sectional survey design was used for univariate and multivariate analyses of thirty one empirically or theoretically derived variables. Previously collected data was retrospectively analysed for 1043 consecutive patients undergoing first time isolated coronary artery bypass graft surgery at a single National Health Service trust during 2005.

By univariate analysis twenty variables were found to be associated with postoperative length of stay as a continuous variable, and as a categorical dichotomy of either less than or equal to five days or more than five days. Multivariate analysis of these variables showed that both postoperative length of stay and discharge within five days of surgery were poorly predicted. However, the models developed were much better at predicting postoperative lengths of stay greater than five days.

Phase II

Another cohort of 503 patients was used to prospectively validate the models. The potential influence of perceived stress and health locus of control was also investigated. These variables were not associated with either outcome.

This study identified areas for further research, including the potential of other psychosocial variables to improve the predictive ability of the models. This would increase the utility of the models in practice and contribute to improvements in both the quality of the patient journey and the business objectives of healthcare organisations.

ABBREVIATIONS

ANOVA .... Analysis of Variance
BDI .... Beck Depression Inventory
BMI......................... Body Mass Index
BSA........................ Body Surface Area
CAD .... Coronary Artery Disease
CABG..................... Coronary Artery Bypass Graft
COPD..................... Chronic Obstructive Pulmonary Disease
CPB........................ Cardiopulmonary Bypass
CSS........................ Canadian Cardiovascular Society
EPR........................ Electronic Patient Record
ICP .... Integrated Care Pathway
IMA......................... Internal Mammary Artery
IMD......................... Index of Multiple Deprivation
LMS........................ Left Main Stem
LREC...................... Local Research Ethics Committee
MHLC..................... Multidimensional Health Locus of Control
MI .... Myocardial Infarction
NSF .... National Service Framework
PAS........................ Patient Administration System
PLOS...................... Postoperative Length of Stay
PSS .... Perceived Stress Scale
PTCA...................... Percutaneous Transluminal Coronary Angioplasty
PTSD...................... Post Traumatic Stress Disorder
PVD........................ Peripheral Vascular Disease
NACS .... National Adult Cardiac Surgical (database)
NYHA .... New York Heart Association
ROC .... Receiver Operator Characteristic
SCTS...................... Society of Cardiothoracic Surgeons
VIF.......................... Variance Inflation Factor

CHAPTER 1

INTRODUCTION

Coronary artery disease (CAD) refers to the narrowing of one or more coronary arteries, usually from atherosclerotic disease, which limits the supply of blood and oxygen to the heart. CAD is the most common cause of death in the UK, accounting for 101,000 deaths each year (Allender et al, 2007).

Coronary artery bypass graft (CABG) surgery offers symptomatic relief from CAD and prolongs life (American College of Cardiology/American Heart Association, 1991). The provision of surgery for CAD has grown steadily over the last 20 years with around 28,000 operations now performed annually in the UK (Patient UK, 2008).

Most patients are discharged between six and ten days after CABG, but the proportion of patients who leave hospital within five days of their surgery has increased to over 20% (Keogh and Kinsman, 1999; 2002). Advances in cardiac surgery, modern anaesthetic techniques and the introduction of early discharge protocols have resulted in dramatic changes to postoperative management that have enabled patients to be discharged earlier in their recovery.

At the same time, the provision of cardiac surgery has been subject to several government papers and initiatives that have directly and indirectly influenced practice towards earlier discharge, either directly home or by transfer to referring hospitals, in order to maximise surgical capacity and throughput (Department of Health, 2000a; 2002a; 2004a; 2004b).

The pressure to increase patient throughput and bed capacity, together with the trend towards shorter lengths of stay has led to increased pressure at ward level to maximise efficiency in the discharge process to ensure "timely discharge" takes place after CABG.

Discharge from hospital has clearly been identified as an area in which the quality as well as the speed of the patient journey can be improved (House of Commons Health Committee, 2002; Department of Health and Royal College of Nursing, 2003; Health and Social Care Joint Unit and Change Agents Team, 2003; Department of Health, 2004a; Hoban, 2004; National Health Service Modernisation Agency, 2004). Whilst the emphasis has often been placed on avoiding delayed discharges, it is equally important to ensure that premature discharges and readmissions are also prevented.

A patient is ready for discharge/transfer when a clinical and multidisciplinary team decision has been made that the patient is ready for transfer (House of Commons Health Committee, 2002). The multidisciplinary team must be confident that the length of stay in hospital is determined by clinical need and that the patient is in the right place to meet their level of need. The patient is "fit for discharge" when the services of acute or specialist staff within a secondary care setting are no longer required and when physiological, social, functional, and psychological factors have all been taken into account (The Department of Health, 2004a).

Improving the timing of discharges is only one part of the wider action needed to reduce unnecessary delays and improve the quality of the whole patient journey. A clear emphasis on early discharge planning that includes co-ordinating care to an expected or predicted length of stay for common conditions and procedures, has rightly been viewed as a key starting point (Department of Health, 2004a; NHS Institute for Innovation and Improvement, 2007).

Much of CABG surgery is elective and, as a result, discharge can be planned for in the preoperative period. However, it is essential to recognise that each patient is an individual and as such discharge planning and expected, or predicted, lengths of stay should take into account the clinical and psychosocial needs of each individual patient. The ability of healthcare organisations and their staff to predict postoperative length of stay (PLOS) or discharge within five days of CABG, from individual patient variables in the preoperative period is therefore an important topic of investigation with clear implications for both the speed and quality of the patient journey.

Admission to and discharge from hospital for CABG is a stressful time for patients and their families and this stress may be increased with shorter in-hospital recovery times. The perception of stress triggered by impending CABG may elicit a number of biopsychosocial responses and coping behaviours in the individual that could potentially impact on in-hospital recovery and PLOS.

Stress for the patients may be reduced if patients and their carers are informed about and their care is managed toward a predicted date of discharge. The Department of Health (2004a) has suggested that not only can length of stay be estimated or predicted for the majority of hospital patients but that patients want to know how long they are likely to stay in hospital. Information about when a patient can expect to be discharged helps them to feel involved in decisions and motivated to achieve goals towards recovery (Department of Health, 2004a).

Preparation for discharge is an integral component of preparing patients for CABG that begins even before admission. The ability to predict PLOS or discharge within five days for individual patients in the preoperative period can facilitate the provision of individualised discharge planning and improve the patient pathway. It can also assist with planning surgical activity, costs, and resource utilisation.

The current study investigates the following research question:

> "Can postoperative length of stay or discharge within five days of first time isolated CABG surgery be predicted from preoperative patient variables?

The aim of the study was to develop and validate local multivariate models to predict PLOS and/or discharge within five days of CABG from preoperative patient variables, in order to facilitate discharge planning that is tailored to the clinical and psychosocial circumstances of the individual patient and also improve co-ordination of care by the multidisciplinary team.

A search and review of the literature revealed that many variables have previously been found to influence PLOS by univariate analysis. These include demographic, physiological, psychosocial, and organisational variables. However, multivariate prediction models of PLOS have been developed almost exclusively from readily available demographic and physiological data and have yet to quantify any variables that may reliably assist in the prediction of PLOS. The inclusion of psychosocial variables in the development of multivariate prediction models of PLOS has been neglected and represents a gap in the current understanding of this complex relationship, hence their inclusion in this study.

The current study further investigated the influence of traditional demographic, physiological and procedural variables on PLOS in a contemporary sample of the first time isolated CABG population in a single NHS trust together with psychosocial variables not previously included in multivariate analyses. The identification and selection of this latter group of variables was theoretically driven using a stress theory.

The Theory of Stress, Appraisal and Coping (Lazarus and Folkman, 1984) was used to provide a theoretical framework to guide the study, identify potentially important variables and explain individual differences in the perception of stress and the relationships that exist between preoperative patient variables and PLOS. This transactional theory is a dynamic model that changes over time with change in any one of the variables and is therefore suited to the research situation.

The design of the study was observational and was conducted in two phases to construct and then validate the models.

Phase I

A retrospective cross-sectional survey design in which data previously collected for contribution to the Society of Cardiothoracic Surgeons (SCTS) Cardiac database together with computer records of 1043 consecutive patients undergoing first time CABG surgery at a single NHS trust in 2005 were reanalysed.

A univariate analysis of 31 patient variables was performed for PLOS as a continuous variable, and as a categorical dichotomy of less than or equal to five days or more than five days. By univariate analysis 20 variables were found to be associated with these outcomes. These variables were then entered into multivariate analyses to develop prediction models and to derive regression equations to predict PLOS and discharge within five days of surgery.

Phase II

The models developed in Phase I were then prospectively validated on another cohort of 503 patients undergoing first time CABG at the same trust between August 2007 and January 2008. PLOS and the probability of discharge within five days were predicted for patients in Phase II of the study using the regression equations developed in Phase I. The predictions were then compared to the patient's actual PLOS.

Two previously unstudied variables; perceived stress and health locus of control, were identified as potential predictors of PLOS and/or discharge within five days of surgery using the theoretical framework of the study. These variables were also investigated in Phase II but were found not to be associated with either outcome.

The results showed that whilst PLOS and discharge within five days of surgery were poorly predicted in both the development and validation samples, the logistic regression models were however much better at predicting where discharge after five days of surgery was likely to occur.

The identification of those patients likely to require longer recovery periods, in preadmission clinics, or on admission, would allow attention to be focused on this group of patients and may lead to greater consistency of care and facilitate the development of strategies that may also reduce PLOS in this group of patients. It potentially would allow the clinical team to concentrate resources upon those likely to require a greater degree of care at a much earlier stage than would ordinarily be possible. If as a result, the PLOS for these patients could be reduced it would create the opportunity for increased patient throughput and thereby bed capacity as well as better patient outcomes.

Although further research is required, the results of the study will clearly assist in improving the patient pathway and maximising surgical capacity and containing costs. The findings are relevant to doctors, nurses who have a responsibility for discharge planning and bed management, other members of the multidisciplinary team, managers of the service, hospital administrators and ultimately patients.

CHAPTER 2

THEORETICAL FRAMEWORK

The Transactional Theory of Stress Appraisal and Coping

Undergoing CABG is a stressful event. The major sources of stress identified include; waiting for surgery, the fear of dying from illness or surgery, being away from home or work, and concerns about pain and discomfort (Fitzsimons et al, 2000; 2003; Kiovula et al, 2001; Gallagher and McKinley, 2007).

The physiological, psychological and social impact of impending CABG may yield different coping responses among patients that could influence in-hospital recovery and PLOS. A theoretical stress and coping framework is therefore appropriate to conceptualise the research situation.

The transactional theory of Stress, Appraisal and Coping (Lazarus and Folkman, 1984) was chosen for the ability of the theory to describe and explain individual differences in the perception and response to stress from the patient's perspective. This chapter describes and evaluates the theory and also applies it to the current research situation.

Section 2.1 describes the theoretical framework. According to Lazarus and Folkman (1984), cognitive appraisal and coping are mediators in the individual's relationship to the environment. Psychological well-being and the level of stress experienced is the result of primary and secondary appraisal, personal and external environmental demands, coping resources, and coping restraints identified at that moment in time.

Section 2.2 applies the theory to the current research situation in order to guide and inform the study, identify potentially important variables for investigation by multivariate analysis, and describe and explain the relationship between these variables and PLOS after CABG.

2.1 THE TRANSACTIONAL THEORY OF STRESS APPRAISAL AND COPING

The conceptualisation of stress varies according to perspective and it has been argued that the number of perspectives highlights the fact that there is no single approach sophisticated enough to capture the multidimensional nature of the stress concept or account for the complexity of the stress process itself (Bartlett, 1998).

The stress and coping paradigm was developed by Lazarus and colleagues over forty years ago (Lazarus, 1966; Lazarus and Folkman, 1984; Lazarus, 1999). The transactional theory of Stress, Appraisal and Coping (Lazarus and Folkman, 1984) is one of the most prominent theories of stress. The model includes three major components; stress, appraisal and coping. Stress is viewed as a complex cognitive evaluation whilst appraisal and coping are proposed as mediators of the stress response.

2.1.1 STRESS

There are three broad approaches to defining stress: the response-based model (Seyle, 1956), the stimulus-based model (Masuda and Holmes, 1967; Holmes and Rahe, 1967), and the transactional model of stress (Lazarus, 1966; Lazarus and Folkman, 1984).

Following the identification of the “flight or fight syndrome” to describe the physiological processes related to stress (Cannon, 1914), early conceptual work described stress as a non-specific response of the body to noxious stimuli occurring in laboratory rats (Selye, 1936). Selye (1946) described the body’s reaction to physiological stressors as a three-stage process termed the General Adaptation Syndrome.

Early work on the impact of psychosocial stressors focused on the investigation of major life events in humans and continued to be stimulus based (Masuda and Holmes, 1967; Holmes and Rahe, 1967). However, transactional theorists recognised individual differences in the response to these events that were not explained by these models.

Transactional theories of stress are based on the work of social-personality psychologist Richard Lazarus (Lazarus, 1966; Lazarus, Averill & Opton, 1974; Lazarus and Larnier, 1978). Lazarus and colleagues questioned the unidirectional, linear descriptions of stimulus and response models and their inability to account for individual differences; instead focusing on the meaning of an event for the individual rather than a set of physiological responses.

Consequently, the transactional theory of stress was developed to describe the two-way, termed “bidirectional” transactional process, of the response to a stressful life event. The model uses the term ‘transactional’ to indicate that the interaction between the individual and the environment creates a unique new meaning for the individual.

Lazarus (1966) proposed that individual differences in performance under stress were due to the fact that not everyone perceives potentially stressful situations in the same way. He argued that stress is psychologically mediated by cognitive appraisal, a process through which the person evaluates whether a particular encounter with the environment is relevant to his or her well-being, and that an event is only stressful if it is appraised as such by the individual.

Lazarus and Folkman (1984) developed their theoretical framework to examine the concept of stress at multiple levels of analysis and to specify antecedents, processes, and outcomes that are relevant to the phenomena and concept of stress. Because cognitive appraisal rests on the individual’s subjective interpretation of a transaction, the theory is considered, phenomenological as well as cognitive and transactional (Lazarus and Folkman, 1984).

Within the theory of Stress, Appraisal and Coping (Folkman, 1984; Lazarus and Folkman, 1984; Lazarus, 1991; 1999), stress is conceptualised as a process-oriented relationship between the person and the environment. According to Folkman (1984) the process-oriented relationship has two distinct meanings; that the person and the environment are in a dynamic relationship that is constantly changing and that this relationship is bi-directional with the person and the environment each acting on the other. Their definition of stress emphasizes the relationship between the person and the environment. Stress is defined as "… a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being" (Lazarus and Folkman, 1984: 19).

Cognitive appraisal determines the quality and intensity of perceived stress, which in turn, influence a person's selection of coping strategies and the effectiveness of those strategies (Folkman, 1992). The appraisal and coping processes incorporate five major concepts: event, appraisal, coping, immediate effects, and long-term effects (Figure 2.1.1). The event refers to the occurrence of a stressor and the perception of that stressor represents the starting point of the appraisal and coping processes. The remaining concepts are now considered in more detail.

2.1.2 APPRAISAL

The appraisal process is the foundation of the model in which the meaning of a stressful event is determined. The process-oriented relationship of stress is the basis of the appraisal process as the event is evaluated with respect to its significance for the person's well-being.

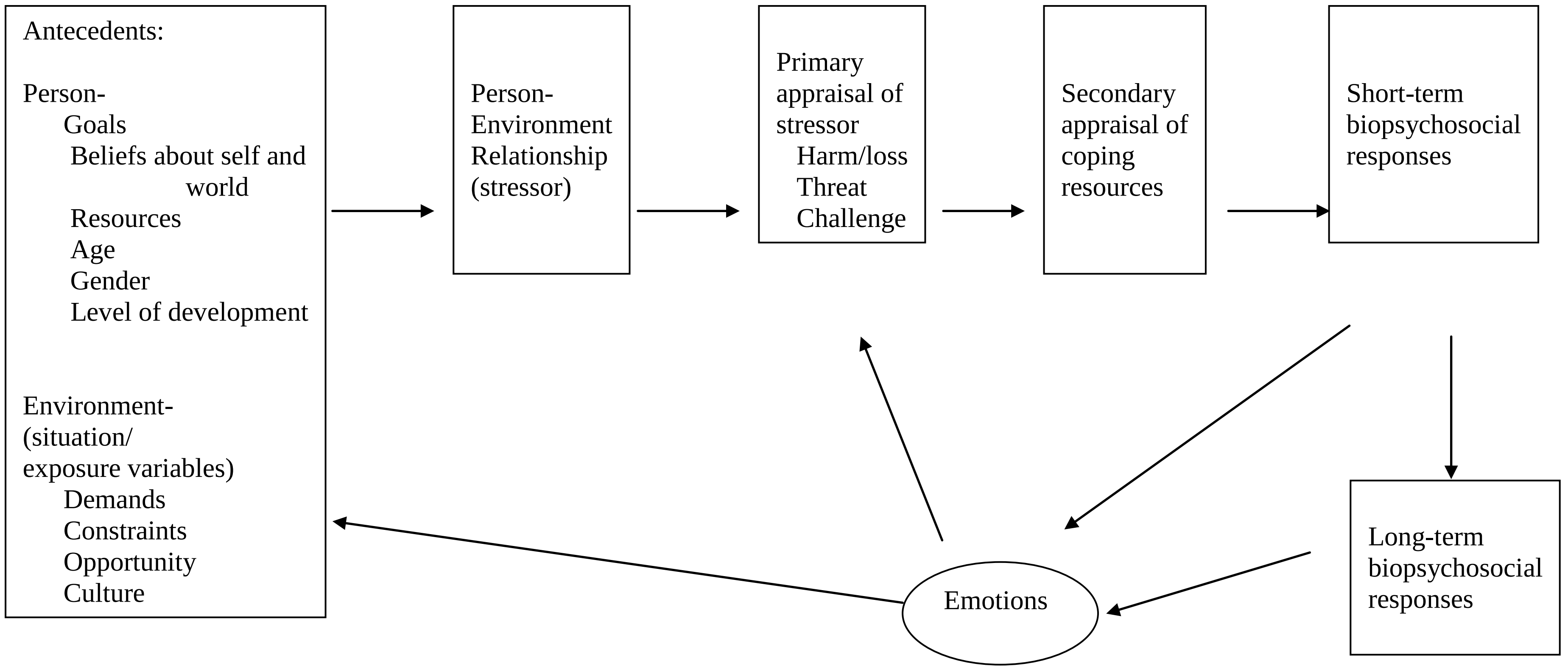


Figure 2.1.1: Lazarus's Stress and Coping Model (2000)

Source: Skybo, T. (2005) Witnessing Violence: Biopsychosocial Impact on Children. Pediatric Nursing. 31(4): 263-270, p264.

Appraisals are influenced by both personal and situational factors. Personal factors that are important determinants of appraisal include commitments and beliefs. Situational factors include novelty, predictability, event uncertainty, imminence, duration, and temporal uncertainty. Personal and situational variables are viewed as interdependent components of the dynamic person-situation relationship and are considered antecedents of appraisal that have the potential to contribute to or diminish threat.

Lazarus and Folkman (1984) identified three kinds of cognitive appraisal; primary appraisal, secondary appraisal, and reappraisal.

2.1.2.1 Primary Appraisal

Primary appraisal determines what the event means to a person's well-being as the individual evaluates what is at stake, and brings emotional quality to the event. The initial evaluation of an event may be appraised as irrelevant, benign-positive or stressful (Lazarus and Folkman, 1984).

Irrelevant encounters have no implications for a person's well-being whilst benign-positive appraisals occur if the outcome of an encounter is construed as positive. Stress appraisals are further categorised as harm/loss, threat, and challenge (Lazarus and Folkman, 1984; Folkman, 1992). Harm-loss appraisals consist of damage that has already occurred. Threat refers to the potential for harm or loss and is characterised by negative emotions such as fear, anxiety and anger. Challenge appraisals are generally more positive and reflect the anticipation of mastery or a beneficial outcome, and are characterised by pleasurable emotions such as eagerness and excitement.

If the occurrence is appraised as a harm/loss, challenge or threat, the event is judged as stressful and secondary appraisal of the occurrence then occurs.

2.1.2.2 Secondary Appraisal

Secondary appraisal incorporates an individual's evaluation of available coping resources as coping options are identified and their efficacy in reducing potential harm is considered. The individual's perceived ability to cope and the changeability of the event are relevant to the secondary appraisal process (Folkman et al, 1991).

Secondary appraisal is influenced by both antecedent personal variables and exposure variables. Personal variables refer to factors such as the individual's coping behaviours and support systems. These depend on the person's past experiences in similar situations, personality traits, personal values, problem-solving skills, morale, cultural background, social group, family situation, and coping resources such as health, energy and positive beliefs (high self-esteem and hope).

Belief is among the most important factors affecting cognitive appraisal and determines how a person evaluates and perceives his relationship with the environment. There are two main categories of belief; belief about personal control and existential belief. Personal control relates to the individual's belief in his ability to control the outcome of events. Existential belief relates to concerns such as faith in god and fate, and helps people create meaning and maintain hope in the face of a stressful situation.

Exposure variables define the extent to which a threat of the stressor is experienced: the nature, imminence, ambiguity and duration of the event and the availability of resources to facilitate coping such as socioeconomic factors, perceived social support and material resources.

2.1.2.3 Reappraisal

Reappraisal occurs based on new information from the environment, or changes in the individual and the event, which may be reappraised as changeable or benign.

The appraisal of a stressful event is followed by consciously selecting a coping strategy to attempt to reduce the stressor's perceived intensity or to build resources or abilities to deal with it, and is dependent upon the appraisal of coping resources.

Although appraisal is viewed as a rational process, it is influenced by many factors such as personality that can lead to distorted or biased conclusions. The manner in which individuals appraise an event has direct implications for their emotional reactions as well as how they will cope with the situation.

Cognitive appraisal may occur at all levels of a person's consciousness and does not follow a predefined sequence. Primary and secondary appraisals are interdependent processes that act concurrently whilst coping is subject to continuous appraisals and reappraisals of the changing person-environment relationship (Lazarus and Folkman, 1984).

2.1.3 COPING

Coping is the process through which the individual manages an event appraised as stressful. Coping is defined as a dynamic process of "constantly changing cognitive and behavioural effort to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person (Lazarus and Folkman, 1984: 141).

The view of coping being a transaction between the individual and their environment as he or she sees it, emphasizes individuality, with a person's coping style being a function of the circumstances, their perception of the circumstances and what they bring to the situation in terms of past history of coping and personality.

Coping theory had previously been dominated by animal experimentation and psychoanalytic ego psychology. According to Lazarus and Folkman (1984) these two approaches are limited by their focus on coping traits and styles rather than processes, and equating coping with mastery over the environment and confounding coping with the outcome.

The process-oriented rather than trait-oriented definition implies a distinction between coping and automatic adaptive behaviour by limiting coping to demands that are appraised as taxing or exceeding a person's resources. By defining coping as efforts to manage, this includes anything that the person does or thinks, regardless of how badly or well it works, so as not to confound coping with outcome. The word manage avoids equating coping with mastery, where managing may include minimising, avoiding, tolerating and accepting as well as attempts to master the environment (Lazarus and Folkman, 1984).

The concepts of coping strategies and coping styles are often used interchangeably within the literature. To coping theorists and researchers, a coping style is a psychological disposition or trait that reflects a person's tendency to respond in a predictable manner when confronted with particular types of situations; whilst a coping strategy is a state measure, reflecting an actual coping response following a particular source of stress appraised as stressful. In contrast to trait approaches that view coping as a stable personality dimension, Lazarus and Folkman (1984) consider coping to be a process that changes over time and across situations.

The cognitive and behavioural methods used to manage the stressful situation serve two functions; managing or altering the problem, and also regulating emotional response. The model postulates that either a problem-focused or emotion-focused coping strategy is used by an individual after the appraisal of a situation although most coping efforts include aspects of both forms of coping (Folkman and Lazarus, 1980; Lazarus and Folkman, 1984; Folkman et al, 1986a).

Problem-focused coping, attempts to manage or alter the circumstance creating harm, challenge or threat, and occurs when the stressful event is perceived as amenable to change by thinking, planning and putting their coping plan into action.

The function of emotion-focused coping is to regulate the emotional response to these demands which cannot be modified. Theoretically, problem-focused and emotion-focused coping often occur concurrently and can both facilitate and impede each other in the coping process.

Eight categories of coping strategies have been identified (Folkman, Lazarus, Pimley and Novak, 1987): confrontive, planful problem-solving (problem-focused), distancing, self-controlling, accepting responsibility, escape-avoidance, positive reappraisal of coping behaviours (emotion-focused), and seeking social support (problem- and emotion-focused).

An individual's choice of coping strategy is related to perceived control; the general belief an individual has concerning the extent to which the outcome is under the control of the individual. Problem-focused coping is used more frequently if control is high and emotion-focused coping employed when little can be done to change, reduce or eliminate the source of stress (Folkman et al, 1991; Lazarus, 1999).

The decision as to what should be done about a threat/harm appraisal is dependent upon the appraisal of coping resources. Coping resources include health and energy, positive beliefs, problem-solving skills and social skills. Coping resources are not constant over time and the relationship between resources and coping is mediated by constraints. Three types of constraint might hinder a person's ability to use coping resources: personal constraints, environmental constraints, and extreme levels of threat.

Personal constraints are internal cultural values and beliefs that proscribe certain types of action or feeling, and psychological deficits that are a product of the person's unique development (Lazarus and Folkman, 1984: 165). Environmental constraints interfere with optimal use of resources by thwarting a person's coping efforts; whilst extreme levels of threat create intense emotional reactions such as fear that interfere with the ability to enact effective problem-focused coping or leads to emotion-focused strategies (Lazarus and Folkman, 1984: 168).

Lazarus and Folkman (1984) make it explicit that coping processes are not inherently good or bad, but that the adaptive qualities of coping processes need to be evaluated in the specific stressful context in which they occur.

Maladaptive coping can adversely affect physical and emotional health. Within the social and behavioural sciences there has been a proliferation of coping research since the work of Lazarus (1966) which has offered an insight into why some individuals fare better than others when encountering stress in their lives. Coping as a distinct field of psychological inquiry emerged during the 1970s and 1980's.

2.1.4 IMMEDIATE AND LONG-TERM EFFECTS

Whilst the process approach makes it difficult to conceptualise and assess a person's overall coping style, the prime importance of appraisal and coping is that they affect adaptational health outcomes. These adaptational health outcomes are conceptualised as being immediate and long-term.

The model refers to two types of immediate effects: event outcome and emotion outcome (Lazarus and Folkman, 1984). Event outcome corresponds to the resolution of the stressful event that results from the coping process and can be favourable, unfavourable or absent. Emotion outcome refers to positive and negative emotion.

Long-term effects refer to three major classes of adaptational outcomes: social functioning, morale, and somatic health (effective, affective and physiological outcomes). Social functioning reflects the "effectiveness with which the demands of a specific encounter are managed" (Lazarus and Folkman, 1984: 183). Morale corresponds to the "positive and negative affect a person experiences during and after an encounter" (Lazarus and Folkman, 1984: 183). Somatic health refers to the physiological changes that are generated by the encounter.

A favourable resolution concludes the coping activity and leads to positive emotion and beneficial long-term effects. An unfavourable resolution or no resolution calls for additional coping efforts and generates negative emotion and detrimental long-term effects (Lazarus and Folkman, 1984).

2.1.5 APPLICATION OF THE MODEL

The stress, appraisal and coping model has been widely accepted and tested in several studies using the Ways of Coping Scale (Folkman and Lazarus, 1985; Folkman et al, 1986a; 1986b; 1987). The model has been utilised as a theoretical framework for many studies of stress and coping and applied to research in many diverse fields including spirituality, counselling, as well as sport, community, social and occupational psychology and qualitative and quantitative nursing research (Peterson et al, 1996; Carlson, 1997; Jickling et al, 1997; Hanton, 1998; McConkie-Rossell and Sullivan, 1999; Sweet et al, 1999; Provencher et al, 2000; Anshel et al, 2001; Reynaud and Meeker, 2002; Kennedy et al, 2003; Hammermeister and Burton, 2004; Rasmussen et al, 2004; Ahmad et al, 2005; Gall et al, 2005).

Several researchers have also used the model to provide a theoretical framework for studies of patients undergoing cardiac surgery; see for example Rice et al, (1992) and Ben-Zur et al, (2000). The findings of studies applying the model generally support the theory that cognitive appraisals of stressful events influence subsequent use of coping strategies. However, whilst Lazarus and Folkman (1984) conceptually subdivided appraisal into two interdependent components: primary and secondary, it has been noted that many appraisal studies have converged both primary and secondary appraisal (Lazarus, 1999).

The transactional theory of stress and coping is therefore considered a useful framework for both clinical nursing practice and research. It is now applied to the current research situation in order to enhance the understanding of the appraisal of stress and the mediation of the stress response to impending CABG surgery. The theory will also be used to conceptualise the theoretical influence of predicting PLOS on the quality and speed of the in-hospital patient pathway as well as guiding the development and validation of the multivariate prediction models.

2.2 STRESS, APPRAISAL AND COPING: THE MULTIVARIATE INVESTIGATION OF POSTOPERATIVE LENGTH OF STAY AFTER CORONARY ARTERY BYPASS GRAFT SURGERY.

As identified in section 2.1 the transactional theory of stress, appraisal and coping (Lazarus and Folkman, 1984) has a broad application and has frequently been used to explain and predict phenomena, to identify problems, develop interventions, guide practice, and direct research. It can account for individual differences in response to stressful events and has previously provided a theoretical framework for studies involving patients undergoing cardiac surgery (Rice et al, 1992; Ben-Zur et al, 2000).

This section therefore applies the theory of stress, appraisal and coping to the multivariate investigation of PLOS after CABG in order to conceptualise the role that predicting PLOS may play in the patient pathway, to explore the complex influences of patient variables on PLOS and identify potentially important variables for investigation.

Based on the theory of stress, appraisal and coping, impending CABG is an event conceptualised as a stressful phenomenon in which the appraisal and coping processes are central.

2.2.1 STRESS

Within the transactional model, stress is neither in the environment nor in the person but a product of their interplay (Lazarus and Folkman, 1984: 354). Thus, applying the theoretical approach means that the research situation must be viewed transactionally and seen as a product of the interplay between the person and the environment. The prospect of CABG is therefore redefined as a person-environment relationship in which stress may occur if the forthcoming surgery is appraised by the patient as taxing or exceeding his or her resources and also being potentially harmful to their well-being.

The individual patient's response to impending CABG is mediated by their cognitive appraisal of this event and their ability to cope with it. As such, the theory can be used explain individual differences in the way patients respond to CABG in the preoperative period.

2.2.2 PRIMARY APPRAISAL

Primary appraisal consists of the individual's initial interpretations about what is at stake, and whether the environment is stressful or relevant to the person's well-being. Accordingly, the patient will evaluate the implications of impending CABG for their well-being.

This appraisal is shaped by personal variables including commitments, beliefs and resources, and also by situational variables including the nature of the threat and its imminence (Lazarus and Folkman, 1984). Sociological and physiological factors in the environment and physiological aspects of the person's body are also considered to exert their impact on the individual in the appraisal process (Bartlett, 1998).

The theory can therefore explain why variables associated with PLOS such as age, gender, religiousness, mortality risk and the urgency of surgery, can also mediate the appraisal of stress (Weintraub et al, 1989, Contrada et al, 2004). For example, gender and role expectations have been found to affect a patient's perception of CABG with men more likely to perceive CABG as a major life crisis than women (Hawthorne, 1994).

Individual differences in the appraisal of threat are expected to make a difference to the patient's experience of surgery. For example, one patient may appraise the prospect of CABG as harmful whilst another patient may view the event positively. It is not clear if either of these responses is optimum for effective coping but the manner in which a patient interprets the prospect of CABG mediates the level of perceived stress intensity and therefore influences the person's coping responses and their subsequent recovery. Whether perceived stress is associated with postoperative length of stay or discharge within five days of CABG is a research question addressed in the current study.

Based on the theory of stress and coping, it is hypothesised that perceived stress is associated with PLOS. The current study measures and investigates the influence of appraised stress on PLOS using the Perceived Stress Scale (PSS) (Cohen et al, 1983). The PSS is based on the work of Lazarus (1966; 1977) and measures how unpredictable, uncontrollable, and overloaded a person finds their life, all of which have been identified as central components of the experience of stress (Cohen et al, 1983).

The psychosocial literature has identified the preoperative CABG period as associated with significant levels of stress, often due to feelings of uncertainty, loss of control and powerlessness (King et al, 1994; Soehren, 1995; Theobald and McMurray, 2004). The identification of the major sources of stress encountered by CABG patients has facilitated a greater understanding of the needs of these patients and the development of interventions to alleviate stress.

Loss of control has been described as one of the CABG patient's greatest psychological stressors and evidence suggests that stressed individuals are less likely to feel empowered to get well or improve their health (Soehren, 1995). Miller (1992) defined powerlessness as a perception that one lacks the authority to change a situation and related powerlessness to learned helplessness. Characteristics of powerlessness include passivity, dependence on others leading to anger, non-participation in decision-making or care, and expressions of lack of control over outcomes or situations (Fuchs, 1987). This suggests that feeling in control may encourage behaviours that facilitate early discharge after CABG. Whether feelings of control about health are associated with postoperative length of stay or discharge within five days of CABG is also a research question that is investigated in the current study.

Increased patient-participation in their care can contribute to overcoming feelings of powerlessness (Boeing and Mongera, 1989; Moser and Dracup, 1995). Increased patient participation and decisional control are also recurrent themes for interventions to decrease the patient's perception of powerlessness and optimise the patient's psychological preparation during the preoperative period. Interventions include helping patients gain a sense of control by determining learning needs, setting mutual goals and encouraging information-seeking.

The provision of preoperative information allows the opportunity for patients to participate in their recovery. Similarly, estimating or predicting a date for discharge may assist in increasing patient participation in the planning of their discharge as identified by the Department of Health (2004a). Theoretically, predicting PLOS at preadmission or on admission, allows the patient the time and opportunity to make arrangements for discharge. This provides important information for the secondary appraisal of resources, reappraisal, and the subsequent selection of coping behaviours during recovery.

2.2.3 SECONDARY APPRAISAL

Secondary appraisal asks "what can I do about the situation?" as the individual assesses what can be done to overcome or prevent harm, or to improve the situation. Consequently, the patient assesses both the changeability of the situation and their resources for coping with impending CABG.

2.2.3.1 Locus of Control

The concept of locus of control is an antecedent of both primary and secondary appraisal which impacts upon appraisal of coping resources.

The construct originates in social learning theory which proposed that the likelihood of behaviour occurring in a given situation is a function of the individual's expectancy that the behaviour will lead to a particular reinforcement, and the extent to which the reinforcement is valued (Rotter, 1954; 1966). Both functions can operate at a general as well as a situation-specific level.

The locus of control construct has been further developed to address health-related behaviours (Levenson, 1973; Wallston et al, 1976; 1978). Wallston et al (1978) developed the multidimensional health locus of control (MHLC) scale to measure generalised expectancy beliefs with respect to health along three dimensions: internal, external- powerful others, and external-chance or fate.

The internal dimension refers to the extent to which individuals believe their health is the result of their own actions. The external dimensions include powerful others referring to the extent to which individuals believe their health is a result of powerful others, such as healthcare professionals, and chance or fate referring to the extent to which individuals believe their health is owing to chance or fate.

Based on the theory, it is hypothesised that a patient's health locus of control is also associated with PLOS. The MHLC scale is used in the current study to investigate the influence of health locus of control on PLOS. The main prediction from the MHLC theory is that internals are more likely to engage in health promoting activities although the relationships only hold for individuals who value their health (Wallston, 1992). However, the construct may not be generalised and it is important to measure control beliefs that are relevant to the behaviour and the situation in question. Specific MHLC scales have been found to be more predictive than the generalised MHLC scale (Georgiou & Bradley, 1992).

2.2.3.2 Antecedents of Appraisal and Coping

The cognitive appraisal and coping processes activated by impending CABG and the severity of stress are influenced by both personal and situational/exposure antecedents. These processes may in turn modulate neuroendocrine, autonomic, and immunological activity and this may facilitate recovery after surgery (Kiecolt-Glaser et al, 1998). The preoperative variables important in the prediction of PLOS after CABG are now conceptualised as antecedent personal and situational/exposure factors in the appraisal and coping process.

The multivariate relationship between antecedent demographic, physiological and procedural variables with PLOS after CABG surgery has been extensively studied in the development of a statistical predictive model with limited success. By emphasising individual differences in the appraisal of a stressor, the theory may explain why although these variables have been frequently associated with PLOS, they are not good predictors of this outcome.

The influence of demographic variables on the appraisal and coping process has been addressed by Lazarus and Folkman (1984) who argued that while there is a statistical tendency for members of the same gender, class or age to share common psychological characteristics, variations among persons within a group are often as great, or greater than that between groups. Consistent with this argument, there have been both positive and negative associations of stress and coping with the demographic variables of age, sex and educational level in cardiac surgical patients and their families (Hwang, 1991; Marnocha, 2003).

The influence of psychosocial antecedent variables on PLOS have been investigated by multivariate analysis to a limited extent and include: dispositional optimism, religiousness, and social support (Contrada et al; 2004; Johnson et al, 2004; Anderson et al, 2006). However, much of the psychosocial research has investigated the influence of emotional responses to stress such as anxiety and depression on PLOS rather than measures of the patient's perceived stress (Stengrevics et al, 1996; Saur et al, 2001; Burg et al, 2003; Oxlad et al, 2006).

Demographic, physiological, procedural and psychosocial antecedent variables will be included in the current study based on identification by previous research reviewed in chapter 4, or theoretically identified by application of the stress and coping theory.

2.2.2.3 REAPPRAISAL

During the reappraisal process, an individual may change their original perception of a stressor based on new information regarding the changeability of the event and/or their resources for coping with it. Theoretically, the prediction of PLOS may allow for a more positive reappraisal of impending CABG and it's implications for well-being by increasing the predictability of the length of hospital admission, facilitating greater control with regards to planning for discharge, and assisting the patient to expand their coping options.

2.2.3 COPING

The model refers to coping as the cognitive and behavioural methods used to master, reduce or tolerate stress (Folkman, 1984). Coping strategies are those efforts that the individual makes to manage demands that tax or exceed the individual's resources. According to the theory, a combination of coping strategies will be selected by an individual when confronted by a threat that is dependent on their perception of the stress and their resources for coping with it.

Research findings in the cardiac surgical population generally support the view of Lazarus and Folkman (1984) that coping is a dynamic process and people use different coping strategies at different times depending on how they view their changing situation. Qualitative coping studies using content analysis of interview data reveal a number of general coping dimensions reported by cardiac surgical patients. These suggest that coping varies as the patient progresses through the surgical experience and also that patients use multiple coping strategies including prayer, information-seeking and seeking social support (King, 1985; Saudia et al, 1991; Redeker, 1992; Crumlish, 1993; 1994; 1998).

Problem-focused coping such as information seeking and seeking social support appear to be the most frequently used and useful strategies. This suggests that patients need to be kept informed of their plan of care and up-dated of any changes whilst support networks also need to be involved in the patient's care. It is not therefore surprising that researchers consistently highlight the importance of information giving to prepare CABG patients for both surgery and discharge home (McHugh et al, 2001; Doering et al, 2002; DiMattio and Tulman, 2003; Garza et al, 2003; Booth et al, 2004; Theobald and McMurray, 2004).

The various coping strategies employed to relieve the symptoms of stress may influence the behaviour of CABG patient during their early recovery and ultimately influence outcomes including PLOS.

There is some evidence that information seeking can influence PLOS. Bardell and Dimitri (2003) concluded that whilst patient-centred efforts to learn about CABG did not result in increased knowledge of CABG, the motivation to learn may be an important predictor of PLOS. Predictors of decreased PLOS included reading a hospital information leaflet (6.6 vs. 9.5 days) and internet research (5.1 vs. 7.9 days).

The framework could be used to identify the level of information required by different types of individuals. People who prefer active, information-seeking coping strategies and who have internal locus of control are more likely to require detailed information than those who prefer an avoidant approach (Shaw, 1999). Different types of information packages could be developed to suit the different profiles of patients.

Since the classical studies of Janis (1958), Hayward (1975), Boore (1978) and Wilson-Barnett (1979) it has been is generally accepted that psychological methods of preparation for surgery, such as giving preoperative information, give the individual a method of exerting personal control and therefore can reduce anxiety, pain and length of hospital stay.

Preparation for discharge is now an integral component of preparing patients for CABG that begins even before admission and such methods are routinely incorporated into preoperative nursing care plans.

Theoretically, preoperative information regarding the patient's individual predicted PLOS can promote the use of problem-focused coping skills and decrease emotion-focused coping. The selection of effective coping strategies may consequently result in more positive emotions and even reduce PLOS.

2.2.4 IMMEDIATE AND LONG-TERM EFFECTS

Although some patients respond in a positive way to impending surgery, many will react to the threat to health, potential physical harm, loss of capacity, and other negative effects of CABG if their coping skills are not sufficient. Stress is identified as multifaceted and is often manifested at three levels: physical, behavioural, and cognitive (Lazarus and Folkman, 1984).

Physiological responses to stress occur as a result of the activation of the sympathetic and adrenal-cortical neuroendocrine systems by the hypothalamus and the subsequent release of adrenalin and cortisol (Selye, 1956).

Acute stress may be either positive or negative. The acute stress response is adaptive preparing the body for “flight or fight” by increasing heart rate, blood pressure, breathing, metabolism, and the production of leucocytes.

The stress is positive when the individual is coping effectively and does not feel threatened. In this instance the sympathetic system is more active than the adrenal-cortical system and this will be indicated by elevated levels of epinephrine and norepinephrine in the blood.

When the individual feels helpless and is not coping effectively the stress is negative. The adrenal-cortical system will be more active than the sympathetic system and this is indicated by elevated blood levels of cortisol (Atkinson et al, 1990).

Chronic stress is negative and an over activated autonomic nervous system can have a detrimental affect on heath.

Behavioural and cognitive responses to stress include anxiety, depression, anger and fear. These responses have all been identified in patients undergoing cardiac surgery (Underwood et al, 1993; Bengston et al, 1994; Burker et al, 1995; McKhann et al, 1997; Timberlake et al, 1997; Jónsdóttir and Baldeursottir, 1998; Fitsimons et al, 2000; Kiovula et al, 2001; Burg et al, 2003).

Some preoperative anxiety is considered adaptive. Janis (1958) suggested that patients showing an average "normal" anticipating anxiety could most adequately do their "work of worrying" and experience fewer emotional disturbances after surgery. Those patients however with either a too high or too low preoperative anxiety experienced more emotional problems after surgery.

Inadequate coping techniques pose a threat to adjustment so it is essential that patients are fully prepared for CABG and discharge and are not overwhelmed, or their ability to cope impeded or constrained by the current trend for shorter lengths of in-hospital stay.

Nurses are frequently identified as being in a unique position to support the patient's coping efforts and intervene when coping strategies are maladaptive (Crumlish et al, 1998). Interventions include providing credible positive information and emphasising the patient's active role in recovery in order to create a sense of control and mastery and reduce feelings of helplessness.

Giving preoperative information which includes a predicted PLOS for individual patients may assist the patient to identify and develop effective coping strategies, and is consistent with secondary appraisal and the stress and coping perspective.

Communication and coordination of care towards the predicted date of discharge can prepare the patient for coping on discharge and can help to strengthen existing coping strategies, thereby reducing the likelihood of negative stress occurring during recovery and delaying discharge. In contrast, the uncertainty and loss of control associated with not having a predicted date of discharge may close these avenues of coping and anxiety and stress is therefore more likely to escalate when PLOS is not predicted, communicated and used to coordinate care by the multidisciplinary team.

Further research is required to identify effective ways to ease the psychological impact associated with the preoperative CABG period. However, the theory is suitably flexible for use as a framework for the development and testing of such interventions and strategies which can help individuals in the face of unavoidable threat. Appraisals should be measured prior to the occurrence of the stressful event and add to the prediction of subsequent coping.

2.3 SUMMARY

The transactional, cognitive-phenomenological approach to stress recognises the importance of the subjective meaning of an event in terms of an individual's response to it.

The theory of stress, appraisal and coping Lazarus and Folkman (1984) reflects a very general approach to the way people cope that is more flexible than earlier models and is able to explain individual differences in stress and coping.

The theory has been widely applied to both nursing and non-healthcare research situations. The application of the theory is useful in the study of patients undergoing CABG where the manner in which a patient interprets this event can be viewed to mediate the level of perceived stress intensity and influence the person's selection of coping strategies during their recovery which may, in turn, influence their PLOS.

As a transactional theory that views stress as a dynamic, multivariate and subjective process between individuals and their environment, the theory has been applied to the current study investigating the prediction of PLOS for individual patients after CABG from multiple antecedent preoperative personal and situational variables. The application of the theory ensures the current research study is designed based on theoretical principles.

CABG has a great impact upon an individual's physical, psychological and social well-being and individuals apply a wide variety of coping strategies during this stressful experience. The theory provides a useful theoretical framework to analyse and explain the processes of appraisal and coping in patients undergoing CABG and can be used to explain individual differences in the way patients respond to this stressor.

The theory can be used to identify and explain the possible pathways by which preoperative patient variables can subsequently influence in-hospital recovery. By applying the theory, two research questions have been derived from a theoretical perspective for investigation in the current study. It has been hypothesised that the preoperative variables of the patient's level of perceived stress and their health locus of control will influence their PLOS and their probability of being discharged within five days of CABG. Further preoperative variables for investigation were identified based on a search and review of the literature in the next chapter.

The theory provides a suitable frame of reference to investigate and discuss the relationships between these antecedent personal and situational variables and their influence on PLOS, and to explore the potential role that predicting PLOS in the preoperative period may play in the appraisal and coping process for patients undergoing CABG and the speed and quality of their in-hospital recovery.

CHAPTER 3

LITERATURE REVIEW – Part 1

Current Trends in Coronary Artery Bypass Graft Surgery

A review of the literature was conducted in order to identify preoperative variables that have previously been associated with PLOS following CABG surgery. This chapter forms the first part of the literature review and examines current trends in CABG surgery and their impact on PLOS. Part 2 of the literature review (chapter 4) examines the preoperative prediction of PLOS after CABG.

Section 3.1 outlines the purpose of CABG and recent developments in surgical practice.

Section 3.2 outlines the political and economic drivers to reduce PLOS that have been reflected in recent government initiatives and policy documents designed to improve patient discharge from hospital.

Section 3.3 examines the impact of increasing patient risk profiles on PLOS.

Section 3.4 examines the changing characteristics of the CABG population in more detail including the changing prevalence of co-morbid conditions and their influence on PLOS.

3.1. CORONARY ARTERY BYPASS GRAFT SURGERY

The purpose of CABG is to relieve angina by restoring the antegrade flow of blood. CABG is used to treat severe coronary atherosclerosis such as left main stem (LMS) disease, three vessel disease with moderately impaired left ventricular function, or diffuse vessel disease. CABG can also improve the prognosis for patients with either more severe or less advanced disease (Eagle et al, 1999).

CABG is performed with the use of cardiopulmonary bypass (CPB) in the vast majority of cases and is the most invasive technique in the coronary revascularisation spectrum. Recent changes in practice designed to make surgery less invasive include, eliminating the need for CPB (off-pump CABG), avoiding manipulation of the aorta, port access surgery, and minimally invasive CABG under direct vision.

How the different surgical techniques influence outcomes after CABG has been addressed in several studies and there is evidence that less invasive techniques may reduce morbidity, mortality and impact upon outcomes such as PLOS (see for example Mehran et al, 2000; Ehsan et al, 2004).

3.1.1 Conduits

Common conduits used for CABG include the saphenous vein, the internal mammary arteries (IMA) or radial arteries. The use of the left IMA to bypass the left anterior descending coronary artery has become standard practice due to its longer patency rate. The IMA is more resistant to atheroma formation owing to the greater ability of its endothelium to influence vascular tone, provide a non-thrombogenic surface, and respond to the inflammatory process. The long saphenous vein is most commonly used to bypass the other coronary arteries (Keogh and Kinsman, 2004).

There was little use of IMA grafts until the mid-1980's, since then arterial conduits have become more popular in recent years and may be the only option available in some patients due to the technical difficulties in finding an appropriate vein for grafting (Keogh and Kinsman, 2004). There is clear evidence that patients receiving an arterial graft have better long-term survival and probably a short-term protective effect as well (Grover et al, 1994; Leavitt et al, 2001; Taggart, 2002).

3.1.2 Cardiopulmonary Bypass

During conventional CABG, CPB provides a systemic circulation while the heart is stopped (Favaloro, 1969). Access to the heart is obtained via a median sternotomy and the ascending aorta is cannulated for CPB. The right atrium is cannulated and blood is diverted from the right side of the heart into the CPB machine where a series of pumps circulate the blood through a membrane oxygenator which oxygenates the blood and removes carbon dioxide, and returns it to the systemic circulation via an aortic cannula. Once blood is circulating through the CPB machine, the body temperature is rapidly reduced and the body's oxygen requirements are reduced. A clamp is then placed across the aorta between the heart and the aortic cannula to ensure that blood from the bypass machine does not flow into the heart, but forwards into the systemic circulation. Cardiac arrest is then induced chemically or electrically to make the heart motionless, with blood and/or crystalloid cardioplegia or cross-clamp with fibrillation respectively, and the ascending aorta is manipulated for the construction of proximal anastomoses for saphenous vein grafts or free arterial grafts (Margerson and Riley, 2003).

CPB and cardioplegia ensure a bloodless and motionless surgical field, and allows the lungs to be deflated to maximise visualisation of the operative site. However, CPB has profound physiological effects and is associated with neurological, inflammatory and circulatory complications.

Cannulation of the heart and the ascending aorta may induce atherosclerotic macro-emboli and the magnitude of the embolic load is correlated with the duration time of CPB (Mark and Newman, 2002). Meanwhile, the contact between the blood and the foreign surface of the CPB circuit activates the complement system and induces a total body inflammatory response in which oxygen free radicals and pro-inflammatory cytokines are activated (Edmunds, 1995). This diffuse inflammatory response may contribute to several postoperative complications that prolong PLOS, including myocardial stunning, respiratory distress, renal failure and neurological injury (De Jaegere and Suyker, 2002).

During CPB the blood is heparinised and diluted with a crystalloid solution to prevent clotting in the extracorporeal circulation and aid movement through the CPB machine respectively. The latter contributes to the low haematocrit and low blood pressure frequently seen in the immediate postoperative period. Heamodilution and haemolysis are direct consequences of CPB and may produce significant coagulopathy, necessitating the transfusion of blood products. Furthermore, the non-pulsatile flow produced by CPB machine is thought to have an adverse effect on the microcirculation, leading to arteriolar shunting that may contribute to postoperative organ dysfunction or failure (De Jaegere and Suyker, 2002).

The process of CPB also activates the sympathetic nervous system and the stress response. One of the outcomes of this response is increased catecholamine secretion, leading to alterations in carbohydrate metabolism which suppresses the release of insulin and stimulates glycogenolysis leading to postoperative hyperglycaemia. The activation of the stress response on the neuroendocrine system can lead to many potential physiological effects, including alterations in metabolism, heamodynamics, and fluid balance. These can all increase postoperative complications such as cardiac, pulmonary, or renal dysfunction (Ascione et al, 1999a; Asimakopoulos et al, 1999).

It is clear that avoiding CPB can reduce the oxidative stress, inflammation, heamodilution, and activation of the stress response; thereby decreasing the risk of neurological, cardiopulmonary and renal complications. Since the mid-1990's awareness of the morbidity attributable to CPB has lead to efforts to find alternatives to conventional CABG with CPB and to reduce the invasiveness of surgery. This has lead to the development of off-pump and minimally invasive techniques in selected patients.

3.1.3 Off-Pump Coronary Artery Bypass Grafting

Minimally invasive approaches performed via a smaller incision have been developed both with and without CPB. However, due to the difficulties of performing limited access CABG and also the success of less invasive percutaneous transluminal coronary angioplasty (PTCA); the development of techniques to reduce the incision length have declined.

Meanwhile, the benefit of avoiding CPB has continued to develop and off-pump CABG via a median sternotomy remains the most clinically acceptable of recent developments. In January 2004, The National Institute for Clinical Excellence issued guidance recommending off-pump CABG to treat single or multiple-vessel disease performed through a median sternotomy (National Institute for Clinical Excellence, 2004).

Off-pump CABG was pioneered by Benetti et al (1991) and Buffolo et al (1996) in South America and continues to be refined. Off-pump CABG refers to CABG surgery on the beating heart without the use of CPB and cardiac arrest. A stabilising device is used to immobilise and stabilise the site of coronary grafting during the anastomosis whilst the heart continues to beat. Off-pump CABG accounted for 17% of CABG procedures in the UK in 2003 (Keogh and Kinsman, 2004).

Off-pump CABG avoids the physiological consequences of CPB and aortic cross-clamp. Compared to CABG with CPB, off-pump CABG produces less oxidative stress and renal dysfunction, fewer cardiac arrhythmias, suppression of the peri-operative inflammatory response, reduced myocardial injury and transfusion requirement, a lower rate of chest infection and mortality, and also a decreased length of hospital stay (Jones and Weintraub, 1996; Ascione et al, 1999a; Ascione et al, 1999b; Kshettry et al, 2000; Ascione et al, 2001; Bowles et al, 2001; Cleveland et al, 2001; Gerritsen et al, 2001; Plomondon et al, 2001; Puskas et al, 2001; Van Dijk et al, 2001; Angelini et al, 2002; Magee et al, 2002; Järvinen et al, 2003; Puskas et al, 2003).

However, whilst there are clear benefits of avoiding CPB, off-pump CABG is technically more demanding because the operative field is less stable and less visible, and it is not suitable for all patients. Conventional CABG with CPB provides the visibility and space to construct anastomoses on all the coronary arteries. This may be more difficult with off-pump CABG and most authors report statistically fewer grafts performed in off-pump groups compared to CABG with CPB (Ascione et al, 1999b; Arom et al, 2000; Czerny et al, 2001; Van Dijk et al, 2001). Consequently, the technical difficulty of off-pump CABG and the completeness of revascularisation are pertinent issues in off-pump surgery (Bonchek and Ullyot, 1998; Cooley and Con, 2000; Khan et al, 2004).

Previously, multi-vessel disease, LMS stenosis, being female, small diffusely diseased vessels, arterial grafts and urgent surgery have been considered contraindications to off-pump CABG but with increasing surgical experience and advancing technology, more higher-risk and technically demanding cases are now selected for off-pump CABG (National Institute of Clinical Excellence, 2004).

Evidence now suggests that factors determining selection of patients for off-pump CABG include female gender, renal failure, and re-operation and that off-pump CABG may be of particular benefit in those subgroups traditionally considered high risk for CABG surgery, such as the elderly, women, and patients undergoing repeat operations (Mack et al, 2004). Subsequently, off-pump CABG is increasingly being carried out on high risk patients with limited physiological reserves who were previously denied surgical revascularisation (Puskas et al, 2001; 2003).

Given the theoretical advantages of avoiding the well-documented adverse effects of CPB on end-organ function, inflammation, and blood coagulation, it is reasonable to expect that off-pump CABG might lead to shorter PLOS.

Following the relatively recent resurgence of off-pump CABG, there have been many studies comparing outcomes of the two approaches. PLOS has been analysed using various study designs including retrospective reviews (Lee et al, 2000; Cleveland et al, 2001), sophisticated statistical analyses such as case matching and propensity scoring (Puskas et al, 2001; Abu-Omar and Taggart, 2002; Berson et al, 2002; Louagie et al, 2002; Haase et al, 2003; Hravnak et al, 2004), and randomised controlled trials (Jones and Weintraub, 1996; Ascione et al; 2000; Ascione et al; 2001; Van Dijk et al, 2001; Angelini et al, 2002; Puskas et al, 2003; Gerola et al, 2004; Khan et al, 2004; Legare et al, 2004; Straka et al, 2004).

The findings suggest that patients receiving off-pump CABG have at least comparable and possibly shorter PLOS compared with patients receiving CABG with CPB.

However, the historical selection bias in favour of patients undergoing off-pump CABG compared with conventional CABG confound the findings of retrospective and non randomised comparisons in this field. In addition, simultaneous advances in anaesthetic and pharmacological management and fast-track techniques that are more likely to be applied to off-pump CABG cases make it difficult to make unequivocal conclusions about the outcomes studied being due to the avoidance of CPB (Puskas et al, 2003).

The decision to perform CABG with or without CPB remains at the surgeon's discretion. Selection criteria vary between surgeons. The advantages of avoiding CPB are well-documented but the potential for sub-optimal operative exposure and heamodynamic instability during off-pump CABG could negatively impact upon both short-term and long-term outcomes (Bonchek and Ullyot, 1998; Cooley and Con, 2000; Khan et al, 2004).

A definitive conclusion about the benefits of off-pump CABG over CABG with CPB is therefore difficult to reach, although it may be generalised that the PLOS of off-pump CABG is less than or equal to CABG with CPB.

3.2. ECONOMIC AND POLITICAL DRIVERS TO REDUCE LENGTH OF STAY

Advances in surgical techniques, including CABG procedures in which CPB is not used, together with changes in postoperative management have enabled patients to recover more quickly than in the past. At the same time, PLOS has been influenced by economic and political pressures to increase surgical capacity, reduce waiting times and also reduce costs.

Over the last decade, government initiatives and policy documents have reflected these pressures and have directly and indirectly contributed to driving current practice towards earlier discharge. This has been motivated by the desire to achieve economic and political objectives as well as improving the overall patient experience (Department of Health, 2000a; 2002a; 2004a; 2004b). Improving and managing the discharge process has been seen as essential to addressing these objectives and several recommendations and guidance for practice have been issued that are consistent with the aims of the current study (Health and Social Care Joint Unit and Change Agents Team, 2003; Department of Health, 2004a; NHS Institute for Innovation and Improvement, 2007).

This section explores the extent to which the observed decrease in PLOS has been achieved due to the implementation of programmes designed to shorten hospital length of stay. In addition, it also explores whether such programmes have actually reduced costs and what the impact on patient outcomes has been.

3.2.1 Increasing demand

As a result of growing evidence of the efficacy of CABG for both the relief of symptoms and prolongation of life, and an increase in resources, the provision of surgery for CAD has grown steadily over the last 30 years (Keogh and Kinsman, 2004, Patient UK, 2008). In addition to expanding surgical capacity, further investment in catheter laboratories across England, the expansion of angioplasty procedures, the patient choice scheme

(Department of Health, 2002a), payment by results, and the 18 week target from general practitioner referral to hospital treatment (Department of Health, 2004b), have inevitably increased demand for CABG in the National Health Service and affected PLOS for the procedure.

Decreasing PLOS has been one way of allowing more CABG operations to be performed thereby meeting increased demand and reducing waiting times for the procedure, where hospitals have the spare capacity to operate on more patients per year. However, whilst earlier discharge programmes and shorter PLOS may save bed days, the number of CABG procedures will be limited by other factors such as the availability of surgeons, theatre time, and intensive care beds. There are also organisational and funding issues, including the increased cost of treating more patients. It logically follows that given the most cost intense activities are during the procedure and in the immediate postoperative period, any increase in the number of operations would have implications for staffing levels and resource costs despite any decrease in PLOS.

3.2.2 Improving the discharge process

Reducing PLOS for elective admissions and minimising delayed discharges have both been identified as key measures to improve and manage the patient discharge process, and viewed as essential to optimise bed capacity, maximise patient throughput, and decrease costs (Department of Health, 2004a; National Health Service Modernisation Agency, 2004). Improving discharge planning in this way has also been highlighted as having a major impact upon meeting government targets such as the four hour trolley wait in accident and emergency departments (Hoban, 2004; National Health Service Modernisation Agency, 2004).

The problems with hospital discharge that have been identified within reports and best practice guidance consistently indicate that the timing of discharge is either too soon or delayed, poorly managed from the patient/carer perspective, or that it is to unsafe environments (House of Commons Health Committee, 2002; Health and Social Care Joint Unit and Change Agents

Team, 2003; Department of Health, 2004a). This highlights the need for research to address the timing and coordination of discharge from a patient safety and satisfaction perspective as well as the optimal use of beds and resource planning concerns.

Avoidable delays in the discharge process are a concern to patients, service providers and healthcare professionals (Department of Health, 2004a; Healthcare Commission, 2004). The Department of Health (2004a) reported that the lack of proactive planning for discharge on or even before admission can mean that patients stay in hospital longer than clinically necessary whilst the Healthcare Commission’s National Patient Survey (2004) revealed that patients identified delays in the day of discharge from hospital as a key area where standards could be improved.

Many of the delays that occur in discharging patients from hospital often relate to communication and the coordination of hospital systems. The causes of delayed discharge that have been cited include a lack of coordination within the hospital multidisciplinary team towards an expected date of discharge, the timing of decisions that conclude that patients are medically fit for discharge, the timing of ward rounds, waiting for test results, medication management and transport arrangements, coordination with community services, resource issues and lack of patient/carer involvement (House of Commons Health Committee, 2002; Health and Social Care Joint Unit and Change Agents Team, 2003; Department of Health, 2004a).

Guidance and recommendations for improving the discharge process focus on discharge planning as part of an ongoing process that should start before admission if possible and should not be an isolated event. It has been recommended that provisional estimated discharge dates should be set within 24 hours of admission, reviewed regularly, and the patient and their carers should be involved at all stages and kept informed by regular reviews and updates of the care plan. The development of protocols for nurse-led discharge, the use of discharge lounges to free beds earlier, arrangements to support rapid discharge, and coordination by a named person or discharge co-ordinator have also been recommended (Department of Health, 1999; Department of Health, 2000a, House of Commons Health Committee, 2002; Health and Social Care Joint Unit and Change Agents Team, 2003; Department of Health, 2004a; National Health Service Modernisation Agency, 2004; NHS Institute for Innovation and Improvement, 2007; 2008).

3.2.4 Estimating a date for discharge

These documents and guidance tools have placed great emphasis on the timing of patient discharge. The notion of estimating a date for discharge arose in response to the Delayed Discharges: Community Care Act 2003 (Department of Health, 2003). Although, this was generally associated with the reimbursement process for delayed discharges rather than improving the patient journey, estimating dates for discharge has remained a key concept in policy guidance (Health and Social Care Joint Unit and Change Agents Team, 2003; Department of Health, 2004a; National Health Service Modernisation Agency, 2004; NHS Institute for Innovation and Improvement, 2007; 2008).

Estimating a date for discharge requires two fundamental steps: a clinical process to estimate and document a date of predicted medical fitness, followed by communication to document and coordinate care towards an estimated date of discharge (Lees and Holmes, 2005). This is consistent with the research question and the aims of the current study to develop and validate a model for the purpose of predicting PLOS and discharge within five days of CABG which can then be used to coordinate patient care.

3.2.5 Programmes to reduce postoperative length of stay

Research shows that PLOS after CABG has clearly decreased. In the late 1980's it was reported that the total length of stay for patients who received CABG surgery was usually 8-13 days (Lazar et al, 1987). It has since been well documented that patients can be, and are, now routinely discharged from hospital much earlier. The trend in decreasing PLOS after cardiac surgery has continued throughout the last two decades with researchers in the field consistently reporting shorter PLOS (Sternlieb, 1987; Krohn et al, 1990; Engelman et al, 1994; Nugent and William, 1994; Nikas et al, 1996; Velaso et al, 1996; Cohn et al, 1997; Weintaub et al, 1998; Moon et al, 2001; Pearson et al, 2001; Keogh and Kinsman, 2002; 2004).

The observed reduction in PLOS may be due in part to Integrated Care Pathways (ICPs). ICPs are multidisciplinary plans of care that outline the timing of interventions for patients with a particular diagnosis or surgical procedure that has a predictable recovery process. Definitions of the ICP concept include; “The combination of clinical practices that result in the most resource efficient, clinically appropriate and shortest length of stay for a specific medical procedure or condition” (Franc and Mayer, 1991: 17).

ICPs were first applied to CABG surgery in the early 1990’s and often incorporate rapid recovery programs or fast track protocols which typically include interventions to minimise length of stay in the intensive care unit, intubation times and PLOS by using shorter-acting anaesthetics, prophylactic medications to prevent predictable complications, accelerating activity, and early discharge programmes (Krohn et al, 1990; Chong, 1992; Jindani et al, 1993; Cotton, 1993; Engelman et al, 1994).

Many studies have described the efficacy of ICP’s in decreasing PLOS after CABG (Sternlieb, 1987; Krohn et al, 1990; Chong, 1992; Jindani et al, 1993; Cotton, 1993; Engelman et al, 1994; Riddle et al, 1996; Riegal et al, 1996; Dunstan and Riddle, 1997; Royston, 1998; Nickerson et al, 1999; Lazar et al, 2001; Moon et al, 2001; Booth et al, 2004). However, the literature is dominated by studies carried out in the USA where state and federal laws regulating hospital reimbursement, the prospective payment system and diagnostic related groups have lead to PLOS becoming a target in reducing healthcare costs as healthcare providers seek to maintain their competitive edge.

3.2.6 Cost and patient outcomes

There have been concerns that programmes designed to save bed days may have a secondary effect on the use of resources elsewhere by increasing morbidity after discharge (Sanchez et al, 1994; Lazar et al, 2001). In the US, the introduction of global capitated schemes, where any readmission occurring within a defined period of the primary procedure is considered part of the original price, may alter financial incentives if reductions in PLOS are off-set by increased readmission rates. In the UK, the geography of regional cardiac centres means that some patients travel some distance for their surgery and there is therefore a tendency to transfer patients back to their local hospital as soon as possible if they cannot be discharged home. Consequently there are concerns that reducing PLOS in one unit simply increases the costs in another unit by redirecting early morbidity to other healthcare providers (Birdi et al, 1995).

However, evidence suggests that the reduction in PLOS appears to have been achieved without increasing adverse patient outcomes (Cohn et al, 1997; Nikas et al, 1996; Velaso et al, 1996; Weintraub et al, 1998; Bohmer et al. 2002). A body of observational before and after evaluation studies generally report reductions in PLOS without an increase in mortality, complication or readmission rates and in some cases suggest that patients discharged earlier actually have lower morbidity, mortality, and readmission rates (Sternlieb, 1987; Krohn et al, 1990 Cotton, 1993; Cowper et al, 1997; Dunstan and Riddle, 1997; Lahey et al, 1998; D'Agostino et al, 1999, Nickerson et al, 1999 Bohmer et al, 2002; Streuer et al, 2002; Booth et al, 2004). Conversely, increased PLOS has been associated with increased likelihood of these outcomes (Stanton et al, 1985; Begg et al, 1996; Cowper et al, 1997; Deaton et al, 1998; Lahey et al, 1998; Bohmer et al, 2002).

However, the above findings must be interpreted with caution. These studies reflect the widely used practice, also used in the current study, of using convenience samples of consecutive patients undergoing surgery at a single centre. Such samples do not, necessarily produce representative findings that can be generalised to the wider population of patients undergoing cardiac surgery at other centres. The lack of control for confounding variables and selection bias in the before and after design of these studies also make it difficult to attribute the decreased PLOS and other outcome measures studied to the ICPs implemented. For example, there is an inherent selection bias in that those patients with shorter PLOS are likely to be healthier than those with longer PLOS.

Differences in readmission rates may also reflect changes in current thinking about the best setting for recovery after surgery that would have occurred without the implementation of shorter recovery pathways. It is also likely that the threshold for readmission to hospital may have increased for the treatment of some complications that are now treated in the community, potentially masking an increase in complications and reasons for readmission.

A further criticism is that whilst mortality and readmission rates are easy to measure they are simplistic indicators of patient outcome. Furthermore, the length and method of follow-up, if any, varies between studies but is often quite short. Readmission rates are questionable measures of morbidity since many centres only track complications and readmissions to their own hospital. Thus it is arguable that early discharge or hospital transfer may actually mask the true morbidity of cardiac surgery by directing it to other healthcare providers. Consequently researchers relying on complications resulting in readmission to the base hospital may grossly underestimate the true morbidity and readmission rate since patients who develop complications away from the primary cardiac centre may be less likely to be re-referred back there.

Hence, it is debatable whether reductions in PLOS reduce the overall healthcare costs or, whether perceived differences in costs between units may be a consequence of transferring costs back to the purchaser rather than an actual difference in overall costs.

Despite the methodological limitations discussed, such studies make the suggestion that earlier discharge after cardiac surgery is a desirable goal in terms of improved patient outcomes, decreased costs, improved waiting list times and also the optimal use of resources. It logically follows that patients who are discharged early are those who are recovering well and the least likely to have problems. If fewer postoperative complications follow shorter lengths of stay, it is possible that earlier discharge may be an effective strategy to reduce the incidence of some postoperative complications. “This fits the proposition that prognosis is best for well persons, and it is better to get well sooner rather than later” (Krohn et al, 1990).

3.2.7 Summary

In summary, it is evident that decreasing PLOS has been a primary target in increasing surgical capacity, patient throughput, and in reducing in-patient cost. Improving the discharge process has been viewed as essential to achieving these aims and has been reflected in policy guidance and recommendations which include planning patient care to an estimated date of discharge.

Whilst it is clear that PLOS for patients following CABG has decreased, the relationship between early discharge after cardiac surgery, patient outcomes and true cost savings is highly complex. The literature demonstrates that enormous cost savings may be realised by the hospital of surgery by decreasing PLOS, although it is not clear if total overall costs are reduced. However, there is evidence that changes in the postoperative management of cardiac patients that have resulted in shorter PLOS may have also led to improved clinical outcomes for patients. However, the measurement of patient outcomes has been over-simplistic and lacking in completeness by relying largely upon morbidity and mortality data.

3.3. INCREASING PATIENT RISK

Whilst advances in surgical techniques and postoperative management have contributed to the observed reduction in PLOS after CABG, these have not occurred in isolation. Concurrent advances in coronary angioplasty and improvements in medical therapy have also occurred and changed the referral pattern for CABG so that more referrals are now for high-risk patients. Meanwhile, the characteristics of the CABG population have also changed in line with the demographics of the general population resulting in a steady increase in the age and risk of the patient selected for CABG in recent years.

3.3.1 Referral changes

The development of percutaneous coronary interventions such as PTCA in the 1980's has dramatically reduced the growth in the CABG caseload and changed the referral patterns for surgical revascularisation so that more of the referrals are now for high-risk patients.

The introduction of PTCA has eliminated many younger CABG candidates with low surgical risk, and has successfully treated many patients who would otherwise have been candidates for CABG (Hudak, 1994). For many patients undergoing percutaneous coronary interventions this will eliminate the need for surgery. For other patients it will delay the need for surgery but for a few, it will precipitate problems necessitating urgent or emergency surgery (Keogh and Kinsman, 2004).

Consequently, the cardiac surgery patient of today is more likely to be older and have more advanced CAD and co-existing conditions as surgeons tend to focus on a worsening case-mix of patients (Keogh and Kinsman, 2004).

The risk profile of patients undergoing CABG has changed markedly in recent years, largely attributed to a reduction in low risk patients and an increase in the proportion of higher risk patients as measured by recognised mortality risk scoring systems (Keogh and Kinsman, 2004). It logically follows that increasing risk profiles will be accompanied by more postoperative complications and increased recovery times. However, the impact on PLOS has been counteracted by rapid changes in knowledge and technology, as well as the economic and political pressures previously discussed.

3.3.2 Risk stratification

The risk of a given patient outcome occurring after surgery is influenced by many factors. Risk stratification models attempt to calculate the impact of preoperative risk factors into a numeric score that represents the probability of a given patient outcome occurring or to stratify patients into low, medium or high risk subgroups. Risk scores have been developed to facilitate decision making and to determine the individual risk, and may be applied to any outcome, such as mortality, the occurrence of a postoperative complication, or PLOS.

Following the analysis of large patient databases, a number of cardiac risk stratification models have been developed for the prediction of postoperative mortality and morbidity in CABG. These are based mainly on patients undergoing procedures with CPB and range from simple additive systems to complex statistical algorithms using logistic regression and Bayesian modelling techniques (Loop et al, 1975; Kennedy et al, 1980; Pierpont et al, 1985; McCormick et al, 1985; Bolsin et al, 1990; Parsonnet et al, 1989; Hammermeister et al, 1990; Higgins et al, 1992; O'Connor et al, 1992; Tuman et al, 1992; Hannan et al, 1994; Magovern et al, 1996; Roques et al, 1999).

The Parsonnet score (Parsonnet et al, 1989) and the European System for Cardiac Operative Risk Evaluation (EUROscore) (Roques et al, 1999) are risk stratification tools widely used within cardiac surgery to calculate the probability of operative mortality. Both include risk factors independent of disease such as age and sex, the presence of co-morbidities, as well as the extent of cardiac disease and also the urgency of surgery.

3.3.2.1 The Parsonnet Score

The Parsonnet Score was developed in North America in the 1980's from a logistic regression model in which 47 potential risk factors were considered to preoperatively determine the risk of mortality within 30 days of surgery (Parsonnet et al, 1989). The scoring system has undergone modifications since it was first introduced in order to decrease subjective input and to improve its accuracy (Parsonnet et al, 1996). The scoring system currently in use requires the collection of 16 variables and can be calculated using all the variables described by Parsonnet et al (1989), or by excluding the two subjective variables "catastrophic states" and "other rare circumstances" (Appendix 1).

These two subjective variables lack standardised definitions and are assigned a weight of 10-50 that is arbitrarily decided by the surgeon. Consequently, including these variables in the calculation can result in inconsistencies and can have a major effect on the overall score. Whichever method is used, the data is weighted to produce a score which is then used to categorise patients into one of five Parsonnet score groups with associated mortality risks (Table 3.3.2.1.1).

TABLE 3.3.2.1.1:
THE PARSONNET SCORE GROUPS

Parsonnet Score	Risk of Mortality	Level of Risk
0-4	1%	Low Risk
5-9	5%	Elevated Risk
10-14	9%	Significantly Elevated Risk
15-19	17%	High Risk
Over 19	31%	Very High Risk

The NACSD report for 2003 shows that the average Parsonnet score of patients undergoing isolated CABG surgery in the UK has risen by two between 1997 and 2003, the equivalent to an increase in predicted mortality of almost 1% over this period (Keogh and Kinsman, 2004).

However, Parsonnet scores have become less accurate as practice has improved and are now considered to overestimate the mortality risk, particularly for high risk patients (Geissler et al, 2002; Asimakopoulas et al, 2003; Nilsson et al, 2006). The weighting of preoperative variables has also changed over time as risk factors have been targeted to minimise their impact and reduce their influence on the surgical outcome. Consequently, while most of the variables remain pertinent, their relative impact on mortality has changed.

Newer scoring systems such as the European System for Cardiac Operative Risk Evaluation (EuroSCORE) (Roques et al, 1999) are based on the same principles as the Parsonnet score but some risk factors and their weightings are different, making allowances for advances in surgical practice and a different patient population.

3.3.2.2 The European System for Cardiac Operative Risk Evaluation

The EuroSCORE was developed and validated for the prediction of in-hospital mortality in cardiac surgical patients in the European population (Roques et al, 1999). A total of 19,030 patients from 128 centres in eight European countries participated in the project. The database generated was subjected to multiple regression analysis to determine which factors were associated with operative mortality and weights allocated to each risk factor based on the odds-ratio. The resultant EuroSCORE is a simple additive risk scoring system that requires the collection of 13 clinical factors (Appendix 2). The percentage predicted mortality for a patient can be calculated by adding the weighted values of risk factors that are present (Table 3.3.2.2.1).

TABLE 3.3.2.2.1
THE EUROSCORE AND MORTALITY RISK

EuroSCORE	Risk of Mortality
0-1	<1.0%
2-3	1.0-1.9%
4-5	2.0-2.9%
6-7	3.0-4.9%
8-9	5.0-9.9%
>9	>9.9%

Based on more contemporary data and a pan-European population, the EuroSCORE is considered to provide a more accurate prediction of operative risk than the Parsonnet score. Again the NACSD report illustrates the worsening patient risk profile with a slow but steady trend towards a higher average EuroSCORE between 1996 and 2001 (Keogh and Kinsman, 2003). Approximately 60% of patients undergoing isolated CABG in the UK fall into the two lowest risk categories (Keogh and Kinsman, 2004).

3.3.3 Mortality Risk and Postoperative Length of Stay

There is evidence that predicted mortality risks are positively correlated with PLOS. An earlier NACSD report (Keogh and Kinsman, 1999) showed that higher Parsonnet scores were correlated with longer than average in-hospital recovery times, and stated that the observed reduction in postoperative stay for isolated CABG patients between 1993 and 1998 could be clearly attributed to lower risk patients with Parsonnet scores less than nine (Keogh and Kinsman, 1999). Similarly, several authors have reported a significant association between increased preoperative mortality risk and PLOS (Miller et al, 1998; Ott et al, 2000; Riordan et al, 2000; Kurki et al, 2001; Peterson et al, 2002; Toumpoulis et al, 2005). Such studies suggest that the preoperative risk profile of the patient could influence their in-hospital postoperative recovery time.

Whilst it may be expected that increasing patient risk profiles will be associated with a greater susceptibility to complications that is reflected in increased PLOS, this has not in fact been observed. Despite the current trend of treating a worsening case-mix of patients, the latest NACSD report shows that approximately 70% of patients undergoing isolated CABG in the UK during the 2003 financial year had a PLOS of less than eight days (Keogh and Kinsman, 2004). This may reflect greater experience in caring for high-risk patients, improved surgical and anaesthetic techniques, as well as changes to postoperative management.

However, the relationship between increasing patient risk and PLOS is clearly a complex one. Earlier NACSD reports show that the proportion of patients discharged within five days of cardiac surgery increased to over 20% in 2001, at the same time, however, the proportion of patients spending longer than ten days in hospital also increased from 15.6% in 1996 to 19.7%

in 2001 (Keogh and Kinsman, 2003).

These findings suggest that PLOS depends on a complex interaction of many variables. The next section examines the changing characteristics of the CABG population and their influence on PLOS.

3.4 CHANGING PATIENT CHARACTERISTICS

The risk profile of patients undergoing CABG has changed considerably over the last few decades (Clark et al, 1994; Ferguson et al, 2002; Bridgewater et al, 2007; Dinh et al, 2008). Data from the latest NACSD report (Keogh and Kinsman, 2004) show that patients undergoing CABG in the UK are increasingly high risk by accepted risk factors such as older age, LMS disease, dyspnoea and preoperative co-morbidities including diabetes, hypertension and renal disease.

Other risk factors have remained relatively stable in the CABG population including; female gender, urgency of surgery, previous myocardial infarction (MI), ejection fraction and peripheral vascular disease (PVD), whilst the severity of angina has actually decreased. However, the influence of some of these variables on PLOS has increased.

3.4.1 Age

The continuing trend towards extending the benefits of CABG to older patients is well established both in the UK and other countries (Rosenfeld et al, 1987; Ugnat et al, 1993; Disch et al, 1994; Haraphongse et al, 1994; Eagle and Guyton et al, 2004; Dinh et al, 2008). The NACS database report 2003 shows a steady increase in the average age of the UK surgical population from 58.4 years to 64.4 years between 1991 and 2003. The average age of patients presenting for CABG is currently increasing at the rate of two years every five years. Over the last decade, the proportion of patients over 70 years old has doubled to 30% and the proportion of over 75 year olds has increased from 2.2% to 10% (Keogh and Kinsman, 2004).

Evidence suggests that advanced age is associated with other preoperative risk factors and an independent predictor of adverse outcomes after CABG, including mortality, postoperative complications and longer PLOS.

Several authors in multiple and diverse settings report that older patients tend to have more preoperative risk factors such as female gender, low ejection fraction, unstable angina, lower body surface area (BSA) and body mass index (BMI), more diabetes, renal dysfunction, PVD, history of cerebral vascular accident, recent MI, LMS stenosis, advanced dyspnoea and angina symptoms, and are also more likely to require emergency surgery (Horneffer et al, 1987; Loop et al, 1988; Mohan et al, 1992a, 1992b; Salomon et al, 1991, Yanagi et al, 1992; Zaidi et al, 1999; Hirose et al, 2000; Zacek et al, 2001; Järvinen et al, 2003; Eagle and Guyton et al, 2004).

Several studies have also found that older patients experience more postoperative complications after cardiac surgery including, bleeding, stroke, atrial fibrillation, wound infection, inotropic drug support and prolonged ventilation (Horneffer et al, 1987; Parsonnet et al, 1989; Weintraub et al, 1991; Higgins et al, 1992; Mohan et al, 1992a, 1992b; Yanagi et al, 1992; Weintraub et al, 1993; Wenger, 1994; Aranki et al, 1996; Kurki and Kataja, 1996; Mathew et al, 1996; Lee et al, 1997; Miller, 1998; Fruitman et al, 1999; Hirose et al, 2000; Zacek et al, 2001; Järvinen et al, 2003).

There is a wealth of evidence that the complexity of caring for older and higher risk patients increases the PLOS for cardiac surgery (Horneffer et al, 1987; Parsonnet et al, 1989; Weintraub et al, 1989; Mohan et al, 1992a, 1992b, Salomon et al 1991; Yanagi et al, 1992; Finkelmeier, 1993; Katz et al, 1995; Lazar et al, 1995; Tu et al; 1995; Miller and Grindel, 1998; Fruitman et al, 1999). In the UK, the NACSD report 2003 shows that older patients stay longer in hospital after CABG, furthermore PLOS is increasing for older patients (over 60 years old) and simultaneously decreasing for younger patients (Keogh and Kinsman, 2004).

Many studies have identified age as a significant variable associated with the length of hospital recovery after cardiac surgery by both univariate and multivariate analysis. The literature is dominated by American and Canadian studies (Lazar et al, 1987; Weintraub et al, 1989; Peterson et al, 1995; Tu et al, 1995; Paone et al, 1998; Reich and Kaplowitz, 1998; Aldea et al, 1999; Rosen et al, 1999; Peterson et al, 2002; Contrada et al, 2004; Johnston et al, 2004; Anderson et al, 2006). However, the finding appears to be consistent over time and across the cardiac surgical populations of countries with differing cultures and healthcare systems including; Belgium (Mohan et al, 1992b), Finland, (Järvinen et al, 2003), Japan (Yanagi et al, 1992; Hirose et al, 2000) as well as the United Kingdom (Mounsey et al, 1995; Naughton et al, 1999).

However, it is not clear whether the influence of age on postoperative recovery and PLOS remains when younger and older patients are matched according to mortality risk classification or after adjustment for co-morbidity. Whilst some authors have reported few significant differences in PLOS between younger and older patients for these outcomes (Miller and Grindel, 1999; 2001), others report that longer PLOS remains associated with elderly patients (Johnson et al, 2002). However, these findings must be interpreted with caution, as the patients were only matched for age, and risk classification or co-morbidities. They were not comparable in other terms with the older patients, who were more likely to be female, have a lower BSA, widowed, living alone, and retired than the younger patients. These variables may also influence the speed of recovery and discharge from hospital after cardiac surgery.

3.4.2 Gender

The latest available data from the NACS database shows that women have consistently comprised about 20% of isolated CABG patients since 1997, although the proportion of women increases with increasing age. In the pre-menopausal age group (less than 50 years) only 13.7% were female but in the over 80 years age group the proportion of women more than doubled to 31.7% (Keogh and Kinsman, 2004).

Coronary heart disease has traditionally been viewed as a disease of middle-aged men (Jensen and King, 1997). Men develop CAD at younger ages with the onset of the disease in women beginning as they approach the menopause, possibly due to the protective effect of oestrogen, although this is negated by the development of diabetes prior to the menopause (American Heart Association, 1998).

The literature generally suggests that women are older than men when they develop CAD, are referred for surgery later in the course of CAD, and are older at the time of surgery (Fisher et al, 1982; Taylor et al, 1989; Khan et al, 1990; O'Connor et al, 1993; Eaker et al, 1989; Moore, 1995, Aldea et al, 1999).

Various theories exist as to why women present for CABG when they are older and with greater disease severity. Hussain et al (1998) suggested that a widespread international referral bias existed with women less likely to be referred for diagnostic and revascularisation procedures and physicians adopting less aggressive management approaches to CAD in women.

Studies analysing sex-adjusted data show higher CABG utilisation rates for men, more intensive interventions, more vessels bypassed and more frequent use of arterial grafts (O'Connor et al, 1993; Hussain et al, 1998; Aldea et al, 1999; Williams et al, 2000; Keresztes et al, 2003; Woods et al, 2003). It has also been suggested that women are less likely to accept short-term mortality risks until they are more severely ill, and are more likely to be widowed and live alone with less social support to seek care (Ayanian and Epstein, 1995; Ayanian et al, 1995).

Women have traditionally been excluded from research within the speciality but more recent studies have included data on both men and women and document gender variations in both the presentation of CAD symptoms and generally worse postoperative outcomes after CABG for women, including longer lengths of stay.

The literature frequently suggests that women have a less favourable physical and psychosocial recovery after CABG than men. Many studies have shown that women have higher morbidity and in-hospital mortality rates, a greater risk of developing postoperative complications, are more likely to be readmitted to hospital, have less favourable physical functioning and ability to carry out activities of daily living, poorer subjective perceptions of their health, higher depression scores, do not experience the same level of symptom relief as men postoperatively, and take longer to resume employment (Sheldon et al, 1975; Bolooki et al, 1975; Reul, et al, 1975; Tyras et al, 1978; Kennedy et al, 1980; Douglas et al, 1981; Zyzanski et al, 1982; Loop et al, 1983; Gardner et al, 1985; Richardson et al, 1986; Kennedy et al, 1981; Hall et al, 1983; Laird-Meeter et al, 1984; Sokol et al, 1987; Rankin, 1989; King et al, 1992; Rahimtoola et al, 1993; Weintraub et al, 1993; Hawthorne, 1994; Artinian and Duggan, 1995; Sjoland et al, 1996; Czajkowski et al, 1997; Sjoland, 1997; Deaton et al, 1998; Miller, 1998; Sabourin and Funk, 1999; King, 2000; Streuer et al, 2002; Vaccarino et al, 2002; Keresztes et al, 2003; Vaccarino, 2003; Keogh and Kinsman, 2004).

Several studies have identified gender as a significant variable associated with PLOS after cardiac surgery by both univariate and multivariate analysis with women consistently reported to have longer PLOS (Weintraub et al, 1989; Tu et al, 1995; Paone et al, 1998; Aldea et al, 1999; Rosen et al, 1999; Peterson et al, 2002; Contrada et al, 2004; Johnson et al, 2004).

The latest available data from the NACS database showed that women consistently tend to stay an extra day in hospital (Keogh and Kinsman, 2004). The report suggests that this is probably due to the fact that women are generally older at the time of surgery and have smaller coronary arteries which mean the operations are more technically demanding.

3.4.2.1 Small body size

Smaller body size may indirectly explain the worse outcomes observed in women rather than a direct gender effect. Body size has been identified as a gender-related variable by several studies reporting that women have a smaller BSA than men (Loop et al, 1983; Khan et al, 1990; O'Connor et al, 1993; Aldea et al, 1999). This corresponds with evidence of increased operative risk among women and smaller people (Fisher et al, 1982; Kennedy et al, 1981; O'Connor et al, 1993).

There is much evidence to support the view that patients with smaller body sizes are at higher risk of hospital mortality after CABG (Fisher et al, 1982; Loop et al, 1983; O'Connor et al, 1993; Edwards et al, 1998; Engelman et al, 1999; Schwann et al, 2001, Keogh and Kinsman, 2004). Research suggests that smaller patients are also more likely to be older, have higher risk scores, more severe dyspnoea classifications, less elective surgery, and to be of Asian ethnicity as well as being female (Yap et al, 2000; Yap et al, 2005).

Research also suggests that smaller patients are more likely to be selected for on-pump CABG rather than off-pump CABG despite evidence that when CPB is used, haemodilutional anaemia is more prevalent in smaller patients and may be a major cause of morbidity and mortality (Defoe et al, 2001; Schwann et al, 2001; Habib et al, 2003). Smaller patients are also less likely to receive an arterial conduit and have less favourable outcomes following CABG surgery including; prolonged ventilator support, acute renal failure, more transfusions and re-operations for bleeding, longer PLOS and a higher death rate than normal sized patients (Engelman et al, 1999; Yap et al, 2000; Schwann et al, 2001; Reeves et al, 2003; Keogh and Kinsman, 2004; Habib et al, 2005; Yap et al, 2005).

Several studies exploring the relationship between body size, gender and mortality after CABG have suggested a possible effect of multi-collinearity between BSA and gender. Smaller BSA has been independently associated with a higher operative mortality after CABG and there is evidence that BSA may actually negate the gender effect on mortality with gender differences not noted in those with smaller BSA and only accentuated with higher BSA. (Weintraub et al, 1993; Philippides et al, 1995 Edwards et al, 1998; Williams et al, 2000). This is not supported by Christakis et al (1995) who found that body size did not increase the risk of operative mortality in both men and women, whilst gender was a significant determinant of operative mortality, even when adjustments were made for body size and preoperative risk factors.

3.4.2.2 Coronary artery size

Smaller coronary arteries are believed to be responsible for the increased risk among women and smaller people (Fisher et al, 1982; Kennedy et al, 1981; O'Connor et al, 1993; O'Connor et al, 1996; Keogh and Kinsman, 2004). Increased risk among those with smaller arteries may be related to increased risk of thrombosis in smaller vessels, technical difficulties of operating on smaller vessels, and decreased short-term patency in bypass conduits grafted to coronary vessels of small diameter.

Sex specific differences in coronary artery diameter have been identified by several studies which show that women have smaller coronary arteries than men even after adjustment for body size (Tyras et al, 1978; Douglas et al, 1981; Golino et al, 1991; Dodge et al, 1992; O'Connor et al, 1996). However, more recent studies have questioned the relative effect of gender on coronary artery size, reporting that whilst BSA and gender are both independent predictors of coronary artery size, body size has a greater influence than gender (Sheifer et al, 2000; Kim et al, 2004).

The complicated relationship between BSA and gender, and BSA and operative mortality was examined in the NACS database report 2000-2001 (Keogh and Kinsman, 2002). Referring to data for the financial years 1997-2001, the findings demonstrated that for both men and women the operative mortality steadily climbs once the BSA drops below 1.9m^2. The report also showed no marked difference in operative mortality between men and women when they are stratified according to body surface and age or according to height and age. The authors of the NACS database report concluded that their findings implied that the observed difference in surgical risk was more likely to be related to body size than to some unexplained physiological difference between the genders, probably due to a combination of the smaller coronary arteries and the relatively greater effect of CPB on the body physiology of smaller people (Keogh and Kinsman, 2004).

3.4.2.3 Other risk factors

There is accumulating evidence that other generally accepted risk factors for poor outcomes after CABG are more common in women than men. As well as older age, smaller BSA, and smaller coronary arteries these include; unstable angina, previous MI, congestive heart failure, diabetes, hypertension and urgent or emergency surgery, although men are more likely to have a history of smoking (Douglas et al, 1981; Eaker et al, 1989; Gardner et al, 1985; Kennedy et al, 1981; Killen et al, 1982; Hall et al, 1983; Khan et al, 1990; Hannan et al, 1992; King et al, 1992; O'Connor et al, 1993; Barbir et al, 1994; Artinian and Duggan, 1995; Ayanian et al, 1995; O'Connor et al, 1996; Hussain et al, 1998; Aldea et al, 1999; O'Rourke et al, 2001; Vaccarino, 2003; Woods et al, 2003; Keogh and Kinsman, 2004). Such factors increase the risk of surgery and postoperative complications and may therefore have influenced past referral patterns and possibly help to explain some of the observed differences in male and female outcomes.

Several studies have investigated whether less favourable outcomes may be attributed to the characteristics of women presenting for CABG. A body of research findings have suggested that it is the differences in surgical characteristics and levels of co-morbidity between men and women that may account for the differences observed in mortality and morbidity. Such studies conclude that men and women appear to have comparable outcomes when adjustment is made for these variables (Douglas et al, 1981; Fisher, 1982; Killen et al,1982; Eaker et al, 1989; Khan et al, 1990; King et al, 1992, Weintraub, 1993; Hannan et al, 1992; O'Connor et al, 1993; O'Connor et al, 1996; Koch et al, 1996; Jacobs et al, 1998; Edwards et al, 1998; Aldea et al, 1999; Koch et al, 2003). However, research suggests that even after adjustment for advanced age, disease severity and co-morbid conditions; women have longer PLOS than their male counterparts (Aldea et al, 1999; Butterworth et al, 2000; Capdeville et al, 2001).

3.4.3 Obesity

Similar to the general population, the proportion of patients undergoing CABG who are obese is increasing. In the UK, less than 25% of CABG surgery patients are of normal weight, 75% are either overweight or obese with over 25% being classed as obese (Keogh and Kinsman, 2004).

In England, the percentage of men classed as obese increased from 13.2 per cent in 1993 to 23.1 per cent in 2005 and from 16.4 per cent to 24.8 per cent for women during the same period (The Information Centre, 2006a). These trends are expected to continue since the UK has a growing and ageing population (National Statistics, 2006) and obesity increases with age (National Audit Office, 2001). It has been predicted that by 2050, 60% of men and 50% of women could be clinically obese (Department of Health, 2007).

There is a higher prevalence of obesity among certain ethnic groups. The Health Survey for England (2004) report showed that among minority ethnic groups Black Caribbean and Irish men, and Black African, Black Caribbean, and Pakistani women had the highest prevalence of obesity (The Information Centre, 2006a).

Women in lower socioeconomic groups have an increased risk of obesity. Whilst no apparent relationship between deprivation scores and prevalence of obesity among men has been reported, among women, those in the most deprived quintile had the highest prevalence of being overweight including obese while those in the least deprived quintile had the lowest prevalence (The Information Centre, 2006a).

In the CABG population, overweight and obese patients are more likely to be female, and suffer from diabetes and hypertension than normal weight patients (Schwann et al, 2001; Reeves et al, 2003).

In contrast to small body size, obesity is not associated with an increased risk of in-hospital mortality following CABG (Kuduvalli et al, 2002; Keogh and

Kinsman, 2004). However, obesity is generally considered a risk factor for postoperative morbidity although existing evidence is contradictory. Being overweight or obese has been associated with more postoperative complications such as wound infection, atrial arrhythmia, impaired renal function, prolonged ventilation and longer PLOS compared to non-obese patients (Kuduvalli et al, 2002; Järvinen et al, 2007; Perrotta et al, 2007).

It has also been argued, however, that overweight, obese and severely obese patients are not at higher risk of adverse outcomes than normal weight patients and are less likely than normal weight patients to require a transfusion (Brandt et al, 2001; Reeves et al, 2003). This is supported by Engelman et al (1999), Schwann et al (2001) and Yap et al (2000; 2005; 2007) who have reported that obesity did not increase adverse outcomes except for a greater rate of sternal and saphenous vein harvest site wound infections, probably due to accelerated arteriosclerosis and delayed wound healing.

Habib et al (2005) concluded that large deviations from normal body size in either direction were associated with increased postoperative morbidity and worse long-term survival. Body size has been identified as significantly associated with PLOS after cardiac surgery by univariate and multivariate analysis (Lahey et al, 1992; Paone et al, 1998; Peterson et al, 2002).

3.4.4 Diabetes

The incidence of diabetes is increasing, particularly type II diabetes secondary to the growing prevalence of obesity (Roberts, 2007). There were an estimated 2.35 million people (4.75%) with diabetes in England in 2006 and this is predicted to increase to more than 2.5 million (5.05%) by 2010 - 9% of which will be due to an increase in obesity (Roberts, 2007). The prevalence of diabetes rises steeply with age: one in 20 people over the age of 65 years in the UK has diabetes, rising to one in five in people over the age of 85 years (Department of Health, 2001b).

People who are overweight or obese, physically inactive or have a family history of diabetes are at increased risk of developing diabetes. The frequency of diabetes in England is higher in men than women, although obese women are almost 13 times more likely to develop Type II diabetes than non-obese women, whilst obese men are nearly five times more likely to develop the illness than non-obese men (National Audit Office, 2001).

Type II diabetes is also more common in people from socially disadvantaged groups and black and minority ethnic communities (Department of Health, 2001b; The Information Centre, 2006b; Roberts and National Diabetic Support Team, 2007; Roberts, 2007).

Diabetic patients have an increased risk of cardiovascular disease including: CAD, cerebrovascular disease, and PVD, resulting from damage to the walls of the large blood vessels, which can then become blocked (Department of Health, 2001b). Many Type II diabetic patients also have raised blood pressure and cholesterol levels which also increase the risk of developing cardiovascular disease, whilst pre-menopausal women with diabetes do not have the same protection against coronary heart disease as other pre-menopausal women (Department of Health, 2001b).

Not surprisingly therefore, the increased incidence of diabetes in the general population has been reflected in the population undergoing CABG. Over 20% of patients undergoing CABG during 2003 had diabetes, an increase of 50% between 1996 and 2003 (Keogh and Kinsman, 2004).

A number of studies have demonstrated an increased short-term morbidity and mortality in diabetic patients after CABG (Herlitz et al, 1996; Cohen et al, 1998; Thourani et al, 1999; Carson et al, 2002; Szabo et al, 2002). Insulin resistance is known to occur during CPB and hyperglycaemia can lead to dehydration, electrolyte disorders, and potential arrhythmias, and has been shown to adversely affect endothelial-dependent vasodilation (Williams et al, 1998).

Several studies have suggested a relationship between glycaemic control and cardiovascular outcomes, septic complications including delayed chemotaxis, diminished granulocyte adherence, impaired phagocytosis, reduced microbiocidal capacity and impaired platelet coagulation, and fibrinolytic function in individuals with diabetes undergoing CABG (Davi et al, 1990; Vague et al, 1992; McMahon et al, 1995; Herlitz et al, 1996; Thourani et al, 1999; Carlson et al, 2002). The importance of long-term glycaemic control in the preoperative period and strict glycaemic control in the peri-operative and postoperative period has been highlighted by several studies showing a decrease in in-hospital morbidity, mortality, and PLOS (Medhi et al, 2001; McAlister et al, 2003; Lazar et al, 2004).

The literature generally suggests that the negative impact of diabetes on morbidity is reflected in a longer PLOS for diabetic patients (Lazer et al, 1995; Rosen, 1999; Thourani et al, 1999; Peterson et al, 2002; Woods et al, 2004). The NACSD report for 2003 showed diabetes has had a stable influence on PLOS between 1999 and 2003 with diabetic patients consistently tending to spend on average an additional 1.5 days in hospital following CABG than patients who do not have diabetes (Keogh and Kinsman, 2004).

It has been suggested that treatment type of the diabetes may be a more important factor and those with insulin-dependent diabetes have a longer PLOS than both non-insulin-dependent diabetes and non-diabetics (Lazer et al, 1995; Stewart et al, 1998).

3.4.5 Hypertension

Data for the general population from the Health Survey for England show that between 1998 and 2005, the prevalence of high blood pressure in England fell slightly in men (from 41% to 39%), and women (from 33% to 29%). The prevalence of hypertension increases with age in both sexes but since 1993 there has been a general tendency for mean systolic and diastolic blood pressure to fall in both men and women, and has been more pronounced among older compared to younger age groups (Department of

Health, 2006).

Conversely, there has been a slow but steady increase in the proportion of hypertensive patients presenting for CABG between 1996-2003 from 44% to 65% which is thought to represent a combination of the effects of a continually aging population and better diagnosis of hypertension (Keogh and Kinsman, 2004). However, hypertension is difficult to identify with certainty in this patient group because many medications used for treating angina are also used for hypertension. Patients with genuine hypertension may not have an elevated blood pressure as a result of any treatment for angina they were given, and therefore would not have been diagnosed with hypertension.

It was concluded from the NACS database report 2003 that there is now little difference in mortality between hypertensive and non-hypertensive patients, but hypertensive patients tend to remain in hospital for one day longer, an increase of 0.6 days since 1999 (Keogh and Kinsman, 2004). Thus hypertension remains a minor risk factor for adverse postoperative outcomes after CABG whilst the influence on PLOS has increased. Several studies have also identified an association between hypertension and PLOS after CABG (Paone et al, 1998; Aldea et al, 1999; Peterson et al, 2002).

3.4.6 Renal function

Renal dysfunction is increasing in both the general population and patients presenting for CABG surgery (Royal College of Physicians of Edinburgh, 2007; Keogh and Kinsman, 2004). Renal impairment is a risk factor for adverse events in cardiac surgery, including a longer postoperative recovery (Bakris et al, 2006; Cooper et al, 2006; Hillis et al, 2006).

Renal disease in the UK population is increasing. It has been estimated that as many as 10% of the UK adult population have early chronic kidney disease, of whom half will have stage three (Royal College of Physicians of Edinburgh, 2007). The prevalence of end-stage renal failure in the UK is 498 patients per million population whilst 110 patients per million population start dialysis each year (The Renal Association, 2005).

The risk of renal failure increases with age, whilst hypertension and diabetes are common causes and people from the South Asian, African and African Caribbean communities and socially deprived populations are more prone to developing these conditions (Department of Health Renal Team, 2004; Royal College of Physicians of Edinburgh, 2007).

Approximately 2% of patients undergoing CABG surgery in the UK have some form of kidney disease, an incidence that has doubled between 1996 and 2003 (Keogh and Kinsman, 2004). Patients with renal failure often have multiple co-morbid disorders, including hypertension and diabetes mellitus. Dialysis-dependent patients have accelerated atherosclerosis and therefore have more severe disease when diagnosed (Keogh and Kinsman, 2004).

Preoperative renal impairment is associated with an increased risk of morbidity, mortality and longer PLOS following CABG, particularly among patients who are dependent on dialysis but even when the impairment is mild (Magovern et al, 1996; Samuels et al, 1996; Rao et al, 1997; Anderson et al, 1999; Durmaz et al, 1999; Liu et al, 2000; Dupuis, 2001; Kan et al, 2004; Powell et al, 2004; Sanjay et al, 2004; Massad et al, 2005; Zakeri et al, 2005; Bakris et al, 2006; Cooper et al, 2006; Hillis et al, 2006).

Data from the NACSD show that presence of renal disease increases mortality risk by five to six times and that on average, patients with renal disease consistently spend an extra five to six days in hospital after CABG, even when the impairment is mild (Keogh and Kinsman, 2004).

3.4.7 Left main stem disease

LMS disease refers to stenosis greater than 50% of the diameter of the left main coronary artery. The percentage of patients presenting for CABG with LMS disease has increased by 60% between 1998 and 2003 from 13.4 to 21.4%, probably because more patients without LMS disease are being treated with angioplasty rather than surgery (Keogh and Kinsman, 2004).

The presence of LMS disease has an adverse influence on outcomes.

Patients with LMS disease are almost twice as likely to die after their operation (Keogh and Kinsman, 2004). LMS disease has also been associated with longer PLOS (Peterson et al, 2002).

Analyses from the NACSD reports show that the difference in PLOS between those with and without LMS disease has increased over the last four years. In earlier analyses LMS disease did not greatly affect PLOS but the latest report shows that patients with LMS disease stay an average of 0.6 days longer in hospital (Keogh and Kinsman, 2004).

3.4.8 Dyspnoea

The term dyspnoea refers to laboured, difficult breathing or breathlessness. It is a subjective symptom that may be due to pulmonary dysfunction, heart disease or a combination of both.

Dyspnoea is a characteristic symptom of asthma, chronic obstructive pulmonary disease (COPD) and heart failure. The prevalence of all of these conditions is increasing in the UK population.

It is estimated that there are 5.2 million people in the UK currently receiving treatment for asthma: 1.1 million children (1 in 10) and 4.1 million adults (one in 12) (Asthma UK, 2004).

About one million people in the UK have COPD which predominantly affects adults older than 40 years who have a history of smoking (Britton, 2003). The prevalence of COPD in the UK is estimated to be 1%, increasing with age to 10% in men older than 75 years. It is present in 18% of male smokers and 14% of female smokers (Britton, 2003). COPD is a risk factor for mortality, morbidity and postoperative complications following CABG (Higgins et al, 1992; Geraci et al, 1993; Edwards et al, 1997; Tuman et al, 1992; Cohen et al, 1995; Ferraris and Ferraris, 1996; Magovern et al, 1996)

Heart failure is a clinical syndrome which occurs when the heart is unable to pump enough blood to meet the body’s demands. CAD and hypertension are common causes. The prevalence of heart failure increases steeply with age; it is estimated that less than 1% of men and women under 65 years have heart failure, increasing to 7% of those aged 75-84 years and 13% of those aged 85 years and above (Majeed et al, 2005).

Both pulmonary dysfunction and heart failure have been associated with increased PLOS after CABG (Lahey et al, 1992; Lazar et al, 1995; Paone et al, 1998; Aldea et al, 1999; Rosen et al, 1999; Peterson et al, 2002; Johnson et al, 2004; Anderson et al, 2006).

Dyspnoea is increasing in the CABG population due to an increase in mild breathlessness. The proportion of patients with dyspnoea presenting for CABG increased from 50% in 1996 to 70% in 2002 (Keogh and Kinsman, 2004).

When due to heart failure, dyspnoea has a significant impact upon mortality. Severe breathlessness is associated with double the risk of mortality than for those without breathlessness, while for those with very severe breathlessness the risk is four times (Keogh and Kinsman, 2004).

Dyspnoea has also been associated with PLOS (Peterson et al, 2002). Breathless patients stay longer in hospital and the worse the breathlessness the longer the stay. The influence of dyspnoea on PLOS has remained relatively stable with patients with very severe breathlessness staying an average of two days longer than patients without breathlessness (Keogh and Kinsman, 2004).

3.4.9 Urgency of surgery

Despite changes in the management and treatment of CAD, the proportion of elective and non-elective CABG cases have remained stable in recent years at approximately 70% and 30% respectively (Keogh and Kinsman, 2004). However, the average age of patients undergoing emergency surgery in the UK between 1997 and 2001 increased from 61.3 to 65.6 years (Keogh and Kinsman, 2002), The urgency of surgery is an important determinant of outcome following CABG. It has a major influence on surgical risk and is a risk factor included in both the Parsonnet score and EuroSCORE.

It is reported that patients undergoing non-elective CABG have a higher risk of mortality and morbidity (Kurki et al, 2003). Urgent cases have an operative mortality approximately twice that of elective patients, whilst emergency surgery has an operative mortality approximately four to five times that of elective surgery (Keogh and Kinsman, 2004).

The urgency of surgery also has a powerful influence on PLOS with non-elective patients spending longer in hospital after CABG (Weintraub et al, 1989; Aldea et al, 1999; Peterson et al, 2002; Burg et al, 2003; Johnson et al, 2004). Trends show that emergency surgery is increasingly associated with longer PLOS compared to non-elective surgery (Keogh and Kinsman, 2002; 2004). During 2003 urgent cases remained in hospital for an average of one day longer postoperatively than elective cases, whilst emergency cases remained in hospital on average 5.3 days longer than elective cases (Keogh and Kinsman, 2004).

3.4.10 Previous myocardial infarction

The proportion of patients presenting for surgery with a previous MI has remained relatively stable since 1996. Nearly half of patients presenting for surgery during 2003 have had a previous MI, whilst one in 20 patients have had two or more (Keogh and Kinsman, 2004).

Combined data from prevalence studies suggest that overall about 4% of men and 2% of women in the UK have had a MI and that prevalence increases with age and is higher in men than in women (www.heartstats.org). Data from the Health Survey for England (2004) also show that the prevalence of MI is relatively higher for men from Indian and Pakistani ethnic groups than the general population (Department of Health, 2005). Other risk factors for MI include diabetes, hypertension, high cholesterol, smoking, obesity and inactivity.

Severe and multiple MIs reduce the ejection fraction of the heart which is associated with worse outcomes. Operative mortality is higher for those who have had a previous MI and increases with each further infarction (Keogh and Kinsman, 2004).

The vast majority of MIs occur over one month prior to surgery. However, a small percentage of patients suffer a MI within one month of their surgery, and some will have required urgent or emergency surgery within 24 hours of the event. The timing of the most recent MI has a profound effect on the outcomes of surgery. Surgery within 24 hours is extremely risky, and is generally reserved for patients where there is no other alternative. The risk for these patients is approximately 11 times the risk for patients who have not had any prior MI and seven times the risk for patients who had their last MI more than 30 days before surgery (Keogh and Kinsman, 2004).

The influence of a previous MI on PLOS has remained stable since the late 1990's. Patients who have had a previous MI take longer to recover from CABG, spending 0.5 days longer in hospital (Keogh and Kinsman, 2002; 2004). Previous NACSD reports have shown that when the number of previous MIs is documented there is a clear demonstration that the greater the number, then the longer the PLOS (Keogh and Kinsman, 2002). Rosen et al (1999) and Peterson et al (2002) have also identified an association between previous MI and PLOS after CABG surgery.

3.4.11 Ejection fraction

The ejection fraction is a standard measure of heart function, referring to the percentage of blood ejected from the left ventricle with each heart beat. The lower the ejection fraction, the greater the impairment; an ejection fraction more than 50% represents good heart function; an ejection fraction between 30-50% represents fair heart function; an ejection fraction of less than 30% represents poor heart function (Keogh and Kinsman, 2004).

Poor ejection fraction is an integral component of heart failure due to CAD and is estimated to account for 70% of patients with heart failure (Keogh and

Kinsman, 2004). Despite earlier predictions that the focus on heart failure in chapter six of the National Service Framework (NSF) for coronary heart disease, encouraging diagnosis and treatment, would increase the number of people with a poor ejection fraction identified in the general population, the NACSD for 2003 showed the percentage of CABG patients with poor heart function has remained relatively stable since 1996. Approximately 65% of CABG patients have a good ejection fraction, 30% have a fair ejection fraction, and 5% have a poor ejection fraction (Keogh and Kinsman, 2004).

Poor preoperative ejection fraction has been shown to adversely affect postoperative hospital mortality and morbidity for patients undergoing CABG (Kay et al, 1995; Eagle and Guyton et al, 2004). Patients with a poor ejection fraction are five times more likely to die after their operation than patients with a good ejection fraction (Keogh and Kinsman, 2004).

It is also evident that patients with a good ejection fraction recover more quickly than patients with impaired heart function. On average, a patient with a poor ejection fraction takes three days longer to recover than patients with a good ejection fraction, and two days longer than patients with a fair ejection fraction (Keogh and Kinsman, 2004). Previous analyses show that the influence of ejection fraction on PLOS has remained relatively stable since 1997 (Keogh and Kinsman, 2002). Multivariate and univariate analyses have also identified an association between ejection fraction and PLOS (Weintraub et al, 1989; Tu et al. 1995; Peterson et al, 2002).

3.4.12 Peripheral vascular disease

PVD is any disease of the circulatory system outside the brain and heart. Although the term can include any disorder that affects any of the blood vessels, it is often used to refer to the presence of blood vessel narrowing in arteries other than the coronary arteries, caused by atheroma.

PVD is present in about 10% of patients undergoing CABG, and has remained relatively constant since the mid 1990’s (Keogh and Kinsman, 2004). Intermittent claudication is the most common form of PVD. In the UK this affects less than 1% of men and women under the age of 55 years but over the age of 55 years, the prevalence increases to almost 5%. At younger ages the prevalence of claudication is almost twice as high in men as in women, but at older ages the sex difference narrows (Fowkes et al, 1991; Bainton et al, 1994). Other factors associated with the development of PVD include smoking, diabetes, hypertension, hyperlipidaemia, obesity, and physical inactivity (Murabito et al, 1997).

During CABG, a fall in blood pressure will cause a fall in blood flow through tissues or organs affected by PVD and may result in irreversible damage to that part of the body. The association between PVD and increased mortality and morbidity in CABG patients is generally accepted (Birkmeyer et al, 1995; 1996; Collison et al, 2006).

In the UK, PVD is associated with a doubling of the mortality rate (Keogh and Kinsman, 2004). PVD has also been associated with longer PLOS (Rosen et al, 1999; Peterson et al, 2002). Trends show that the influence of PVD on PLOS has increased in recent years and patients with PVD currently tend to spend about two days longer in hospital after their operation than those without PVD (Keogh and Kinsman, 2002; 2004).

Several studies suggest that patients with a history of PVD undergoing CABG tend to be older, are more likely to be female and have more co-morbidity but even after controlling for these variables CABG patients with PVD still experience more postoperative complications and longer PLOS (Murabito et al, 1997; Newman et al, 1993; Meijer et al, 1998; Collison et al, 2006).

3.4.13 Angina

The proportion of patients with severe angina at the time of CABG has decreased from 4.5% to 3.8% between 1999 and 2003 (Keogh and Kinsman, 2004).

In the general population the prevalence of angina is consistently higher in men than women and increases with age. Epidemiological studies in the UK estimate that about 8% of men and 5% of women aged 55 to 64 years have experienced angina, increasing to a range of 6% to17% of men and 3% to 10% of women for those aged 65–74 years (Royal College of General Practitioners, The Office of Population Censuses and Surveys of the Department of Health, 1995; Gill et al, 1999; Joint Health Surveys Unit, 1999; Department of Health 2004c). The prevalence of angina is higher for men in Pakistani and Indian ethnic groups than that of the general population (Department of Health, 2005).

Severe angina increases postoperative mortality by more than double and also increases PLOS (Keogh and Kinsman, 2004). The influence of angina on PLOS has remained relatively stable with the greater the severity of angina before CABG, the longer the PLOS. Patients with the severest angina stay 1.5 days longer than patients with little or no angina (Keogh and Kinsman, 2002; 2004).

3.4.14 Summary of patient characteristics

Data from the NACS database report show that the characteristics of the patient population undergoing CABG in the UK are changing (Keogh and Kinsman, 2004). Some accepted risk factors for mortality, morbidity and longer PLOS after CABG are becoming more prevalent in this patient population and include; older age, LMS disease and dyspnoea as well as preoperative co-morbidities including diabetes, hypertension, and renal disease. Other risk factors have remained relatively stable or actually decreased and include; urgency of surgery, previous MI, angina, ejection fraction and PVD.

The impact of increasing age, non-elective surgery, LMS disease, PVD and hypertension on PLOS has increased. Meanwhile, the influence of diabetes, ejection fraction, previous MI, angina, dyspnoea and renal disease has remained stable.

Increasing age, renal disease, PVD and the urgency of surgery are powerful influences on PLOS that are becoming more influential and/or more prevalent in the CABG population. The influence of PVD and non-elective surgery on PLOS is increasing while the prevalence of renal disease is increasing in the CABG population. However, both the proportion of the CABG population over 70 years old is increasing as well as the influence of this variable on PLOS.

Table 3.4.14.1 summarises the trends in risk factors in the CABG population and their influence on mortality, morbidity and PLOS.

TABLE 3.4.14.1
RISK FACTOR TRENDS IN THE CORONARY ARTERY BYPASS GRAFT POPULATION AND THEIR INFLUENCE ON MORTALITY, MORBIDITY AND POSTOPERATIVE LENGTH OF STAY.

Risk Factor	Prevalence in CABG Population	Mortality	Morbidity	Impact on PLOS (days)
Age > 70 years	30% (↑)	+	+	+3 (↑)
Female Gender	20% (↔)	+	+	+1 (↔)
Obesity	25% (↑)		+	+ve
Diabetes	20% (↑)	+	+	+1.5 (↔)
Hypertension	65% (↑)			+1 (↑)
Renal Disease	2% (↑)	+	+	+5-6 (↔)
Poor Ejection Fraction	5% (↔)	+	+	+3 (↔)
Previous MI	50% (↔)	+	+	+0.5 (↔)
Dyspnoea	70% (↑)	Severe X2-4		Severe +2 (↔)
Severe Angina	3.8% (↓)	X2	+	1.5 (↔)
LMS Disease	21.4% (↑)	X2		0.6 (↑)
PVD	10% (↔)	X2	+	+2 (↑)
Non-Elective Surgery	30% (↔)	X2-5	+	+3 (↑)

3.5 SUMMARY

This chapter has outlined recent trends in CABG practice, preoperative patient characteristics and PLOS after CABG.

A general trend to discharge patients earlier after CABG has been observed, facilitated by the introduction of care pathways designed to increase the speed of recovery after cardiac surgery. Despite concerns about the safety of earlier discharge, fears about a corresponding increase in morbidity, mortality and readmission rates have not been realised. In contrast, longer PLOS has been associated with adverse long-term outcomes such as mortality, morbidity and readmission rates (Stanton et al (1985; Begg et al, 1996; Cowper et al, 1997; Deaton et al, 1998; Lahey et al, 1998; Bohmer et al, 2002).

Decreasing PLOS has also been a primary target in reducing in-patient cost. However, the relationship between early discharge, patient outcomes and true cost savings is a highly complex one. The use of early discharge protocols is now routine in cardiac surgery, and no longer only applied to low risk patients, rendering early and adequate discharge planning essential to ensure optimal recovery.

Changes in practice and economical and political drivers to reduce cost and maximise patient throughput have had a dramatic impact on PLOS despite increasing patient risk profiles. Many of the risk factors discussed in this chapter interact in a complex and changing fashion to influence PLOS as well as interacting with other medical conditions, chance effects and differences between and within hospitals. The impact of the differences within and between hospitals is discussed in the following chapters.

As the characteristics of the CABG population are changing, contemporary evaluation of the variables that influence PLOS and their interactions is important to address the research question stated on p14. The application of risk modelling techniques to define these interactions mathematically may enable PLOS to be predicted with greater accuracy. Local calculations could then be applied to individual patient characteristics to generate a realistic PLOS or likelihood of a five-day discharge and help patients make informed decisions regarding their discharge planning and optimise their psychological preparation for surgery.

Predicted or estimated dates of when a patient is “fit for discharge” are central to policy guidance and are important for nurses and the multidisciplinary team to advise individual patients about when they are likely to be ready to go home, providing patients with a goal to work towards and allowing for the arrangement of any necessary services and support.

The next chapter searches and reviews the literature regarding the prediction of PLOS after CABG from multiple preoperative patient variables.

CHAPTER 4

LITERATURE REVIEW – PART 2

Coronary Artery Bypass Graft Surgery and the Preoperative Prediction of Postoperative Length of Stay

The previous chapters have identified the prediction of PLOS as a key component in improving the discharge process and the patient journey (Health and Social Care Joint Unit and Change Agents Team, 2003; Department of Health, 2004a). The theoretical influence of predicting PLOS on the speed and quality of the journey for patients undergoing CABG surgery has also been explored using the theory of Stress, Appraisal and Coping (Lazarus and Folkman, 1984)

The previous chapters have also shown a marked reduction in PLOS in recent years; despite increasing numbers of older and higher risk patients undergoing CABG (Keogh and Kinsman, 2002; 2004). Changes to postoperative management and the demographics of the CABG population mean that any attempt to predict PLOS must be derived from contemporary data so that it is reflective of the CABG patient undergoing surgery today. This chapter now reviews previous studies that have attempted to predict PLOS after cardiac surgery in order to identify which variables are predictive of PLOS and also identify gaps in current knowledge, and to inform the selection of the methods used in the current research study.

Searching the Literature

A systematic review of the literature was conducted to search for information relating to the prediction of PLOS after CABG from multiple preoperative patient variables.

Databases

The Medline/Pubmed database was used to search the literature. The search was conducted without any restrictions on the type of publication, year of publication or language.

Search Terms

The following MeSH terms for CABG and PLOS were identified from the MeSH database and used to search the databases as a major topic:

- **Coronary Artery Bypass**
  - Coronary Artery Bypass, Off-Pump
    - Internal Mammary – Coronary Artery Anastomosis

- **Length of Stay**

Table 4.1 summarises the MeSH terms for CABG and PLOS, and the results of the search.

TABLE 4.1:
SUMMARY OF THE MESH TERMS USED TO SEARCH THE DATABASES

	CABG	**PLOS**
	Coronary Artery Bypass	Length of Stay
	Coronary Artery Bypass, Off-Pump	
	Internal Mammary – Coronary Artery Anastomosis	
Results	35324	4943
Combined Results	**98**	

Search Results

The search strategy generated 98 results (last conducted 13th October 2008). Relevant studies were also identified from reference lists of the articles selected and related links in the database search results.

Inclusion and Exclusion Criteria

Articles were obtained on the basis of the abstract containing information that the study included a multivariate or univariate analysis of PLOS in the adult cardiac surgery population. Research investigating PLOS of both isolated CABG patients and the wider cardiac population including concomitant valve surgery and repeat procedures were included. However, as the models' intended use was to predict PLOS in the preoperative period, only studies investigating variables that can be determined preoperatively and which may therefore assist in the preoperative prediction of PLOS in the CABG population have been included in the review.

These criteria resulted in the selection of nine multivariate analyses (key papers) and six studies examining the univariate and/or additional influence of psychosocial variables on PLOS for review.

The studies identified from the literature search have been divided into the following sections:

> Section 4.1 reviews studies involving multivariate analyses of PLOS after cardiac surgery. The studies reviewed in this section form the key papers of the literature review and tend to consist of analyses including demographic and physiological and procedural variables only.
>
> Section 4.2 reviews studies that have examined the influence of preoperative psychosocial variables on PLOS after cardiac surgery. Such variables have traditionally not been included in the multivariate analyses reviewed in section 4.1 but have been independently associated with PLOS by univariate analysis and demonstrated to account for some additional variance in PLOS after physiological, demographic and procedural variables have been entered into the modelling process. The influence of each of the psychosocial variables identified on PLOS is explored with reference to the theoretical framework of the study.
>
> Section 4.3 concludes the literature review by summarising the findings of the studies reviewed in the previous sections and what is currently known about the preoperative prediction of PLOS after CABG.

The appraisal of each study was informed by the Critical Appraisal Skills Program (2004). Critical analysis and evaluation of the research methods and the findings of the studies were then used to generate research hypotheses and to guide and inform the design of the current study.

4.1 PREDICTING POSTOPERTIVE LENGTH OF STAY FOLLOWING CARDIAC SURGERY BY MULTIVARIATE ANALYSIS.

This section critically evaluates previous studies that include multivariate prediction analyses to explore the combined significance of preoperative variables on PLOS after CABG. These studies form the key papers of the literature review which identify the research designs, samples and statistical methods that have been used to investigate the research question, as well as the findings and gaps that remain in the current body of knowledge

The studies reviewed are arranged in the following groups:

4.1.1 Studies in the United States and Canada

- Weintraub et al (1989)
- Lahey et al (1992)
- Lazer et al (1995)
- Tu et al (1995)

4.1.2 Studies in the United Kingdom

- Mounsey et al (1995)

4.1.3 Investigations of the influence of specific variables on PLOS

- Paone et al (1998)
- Aldea et al (1999)

4.1.4 Studies that compare hospitals

- Rosen et al (1999)
- Peterson et al (2002)

4.1.1 STUDIES IN THE UNITED STATES AND CANADA

An early observational study by Weintraub et al (1989) continues to remain influential due to the clarity and rigour of the statistical analysis. The study investigated the associated and predictive variables of PLOS and prolonged PLOS. Data for preoperative and perioperative (termed preprocedural and periprocedural in the study) was prospectively collected for a population sample of 4,683 patients undergoing cardiac catheterisation followed by first time isolated CABG at two American hospitals between 1981 and 1986.

They found that PLOS had a median and modal value of seven days, and defined a prolonged PLOS as greater than ten days, although no rationale was given for this cut-off point.

The preoperative variables included in the study were; age, gender, angina classification, history of previous MI, hypertension, diabetes, ejection fraction, number of vessels diseased, and urgency of surgery. Following a univariate analysis of each single independent variable, the authors reported that the relative risk of prolonged stay was highest for those patients who were over 70 years old, women, and emergency patients.

Three prediction models were determined based on: 1. Preoperative variables, 2. Perioperative variables, and 3. Preoperative and perioperative variables combined.

Multivariate logistic regression was used to explore the relationship between the predictor variables and the categorical outcome of prolonged stay. A stepwise selection method was used to identify the variables with statistically significant effects for inclusion into the regression model. Prolonged stay was found to be associated with the preoperative variables of age, elective/emergency status, angina class, ejection fraction and gender, and the perioperative variables of wound infection, neurologic event, arrhythmias, pneumonia, MI, pericarditis and mortality.

The prediction models developed from the stepwise logistic regression were then tested on a second cohort of 781 patients in 1987. The coefficients were used to determine the probability of prolonged stay in the validation population, with patients predicted to have a prolonged stay if the model predicted a more than 30% (acknowledged by the authors as an arbitrary cut point) chance of prolonged stay.

Contingency tables of observed and predicted prolonged stay were constructed and than evaluated by performing sensitivities (the proportion of positive cases that were correctly identified as positive), specificities (the proportion of negative cases that were correctly identified as negative), and predictive values to measure the strength of association from zero to one (R^2). The results were more impressive for the models involving perioperative variables.

The preoperative variables of age and ejection fraction, along with major postoperative complications, remained associated in the validation population but emergency surgery, gender and angina class were no longer multivariate associates of prolonged stay. Sensitivity was poor at 0.13 but specificity was 0.95.

The authors concluded that preoperative variables did not permit the reliable prediction of a prolonged stay of more than ten days (predictive value 0.29), but the model involving perioperative complications did provide some ability to predict prolonged stay (predictive value 0.62; sensitivity 0.35; specificity 0.96).

PLOS as a continuous variable was examined by multiple linear regression and was followed by plotting of the residuals to ensure a reasonably normal distribution. Again, the most predictive model included perioperative variables but could predict only 20% of the variation in PLOS. However, PLOS was not normally distributed. Improving the normality by taking the natural log resulted in more variables becoming predictive and the amount of variation predicted by the model increased to 33%.

The authors concluded that their findings suggest that the ability to predict PLOS precisely is limited. Furthermore, greater ability to predict the complications that lengthen PLOS may permit a more refined prediction of PLOS at the time of admission. However, the use of stepwise logistic regression to predict each of the complications from clinical variables found no significant results.

This study is frequently cited by subsequent researchers and elements of the study have been replicated and incorporated into later research. Like many studies of PLOS, it appears to be motivated by controlling hospital costs, and refers to PLOS as an "uncertain" measure of cost. The external validity of the findings is limited by the use of a convenience sample from only two hospitals and although there was a large sample size for the number of variables studied, there was no reported calculation of sample size or power analysis for the validation population.

The authors studied only nine preoperative variables and did not give their rationale for which variables they selected for inclusion in the study. It is therefore possible that important variables may have been excluded. It was also not clear if the decision to discharge a patient was made by the authors or what controls were in place to avoid bias.

The exclusion criteria, the definitions of variables, and the statistical analyses were explicit and sufficiently comprehensive to enable replication of the study, although the stepwise method was not reported. However, since the data was positively skewed and subject to outliers, the model assumptions for linear regression were not satisfied for PLOS and log-transformed PLOS and may have resulted in questionable inferences being drawn from the model.

The authors concluded that they could account for only a portion of the variation in PLOS, but did not discuss the possible reasons for this which may include practice variations and data for variables not gathered. The changes in the multivariate associates of prolonged PLOS between the development and validation populations may reflect temporal changes in what is considered a prolonged PLOS, the patient case-mix, and clinical practice between the two periods.

There are many possible explanations for the observed changes in the relative influence of the variables over time which the authors did not discuss, and there was no comparison of the baseline characteristics of the validation group with the original group in the report. Similarly, the authors did not comment on how the findings could be applied to the general first time CABG population or compare them to any other studies in the field. Consequently, the study describes some of the variables possibly associated with prolonged PLOS, at the given institution, at the time of data collection, and suggests that PLOS is poorly predicted from the variables studied.

Lahey et al (1992) added to what was known regarding the predictors of prolonged PLOS. However, this study was smaller than that of Weintraub et al (1989) and the methods reported lacked sufficient detail and clarity.

Apparently motivated by cost considerations, Lahey et al (1992) analysed 17 preoperative variables of increased PLOS (referred to as LOS in the study) after CABG surgery which they defined as more than 14 days. This cut-off point related to the diagnostic related group limit for CABG patients. The diagnostic related group is an in-patient classification system, used in the United States since 1983, to determine hospital reimbursement for Medicare patients (Mayes, 2007). Patients are classified into groups expected to have similar resource use based on the principle diagnosis, secondary diagnoses, surgical procedure, age, sex and discharge status. The eventual plan was to offer alternative cost-benefit therapeutic options to patients identified at high risk of prolonged PLOS.

The study was observational and retrospective involving a convenience sample of 924 consecutive patients over 60 years old who underwent CABG at a single American centre over a two-year period.

The variables examined were based on previous reports of mortality risk analysis data and were;- age, diabetes, obesity, sinus rhythm, PVD, aortic disease, congestive heart failure, unstable angina, emergency operation, repeat operation, PTCA, hypertension, creatinine, bleeding time, prothrombin time, partial thromboplastin time, and use of an intra-aortic balloon assist device.

Following a univariate analysis of each variable by log-rank test, each variable was entered in a multivariate Cox proportional hazards model to identify significant predictors and derive a weighted score for each variable. By multivariate analysis, six variables were found to be statistically significant predictors of prolonged PLOS; congestive heart failure, use of an intra-aortic balloon assist device, an interaction between congestive heart failure and use of an intra-aortic balloon assist device, creatinine clearance greater than 2.0mg/dl, obesity and age.

The authors reported that an increase in the index score of these variables was directly associated with an exponential increase in PLOS and concluded that their data supported the hypothesis that a mathematical model could predict PLOS after CABG.

However, Lahey's findings could be criticised for using a Cox regression model. Austin et al (2002) have since demonstrated that it performed poorly for predicting PLOS compared to other methods and discouraged its use. The authors of the study stated that they intended to prospectively validate their model in the future. The literature search has however not found any mention of such a study.

The external validity of the findings is limited by the use of a convenience sample from a single hospital. Furthermore, there was no reported calculation of sample size and the authors failed to define their inclusion and exclusion criteria.

The authors did however compare the baseline characteristics of the sample to other studies of mortality. Interestingly the authors did not review or compare their findings to Weintraub et al (1989), referring only to work on mortality.

Whilst more variables were included in this study, inclusion was based on mortality risk data rather than PLOS and so again, important variables that are not mortality risk factors may not have been included in the analysis. The variables investigated were clearly stated but not defined and the methods of data collection were not set out. It is this lack of detail regarding the methods employed by the researchers, together with the over-reliance on mortality research, which limit the usefulness of the findings of this study to the current research situation.

Lazar et al (1995) used an approach similar to Weintraub et al (1989) by developing models for PLOS and prolonged PLOS from both preoperative variables, and preoperative and postoperative variables combined. However, this single centre study was retrospective and had a smaller sample size but studied more variables and used a wider section of the cardiac surgery population.

Similar to the current study, the authors recognised that not all patients undergoing CABG were candidates for early discharge and argued that this should be taken into account when attempting to predict likely PLOS. Funding considerations and policies, rising health care costs and curtailing PLOS were emphasised as the reasons for the study. The aim was to determine which preoperative and postoperative variables contributed to prolonged PLOS and whether by using these variables it was possible to predict which patients would require longer hospitalisation.

The study design was observational and data was collected by retrospective review of patient records. A convenience sample of 194 consecutive patients who underwent CABG at a single US hospital over a four-month period in 1993 and were discharged alive was used. Of these patients, 173 underwent isolated CABG. Prolonged PLOS was defined as more than seven days because fast track and early extubation protocols were in place to discharge patients within seven postoperative days.

A total of 17 preoperative risk factors were included in the analysis; CABG procedure, age, angina classification, intravenous nitroglycerin, intravenous heparin, intra-aortic balloon pump, location before surgery, congestive heart failure, MI, smoking, diabetes, chronic obstructive pulmonary disease, LMS disease, failed percutaneous coronary angioplasty, urgency of surgery, and preoperative length of stay.

A univariate analysis of each risk factor and PLOS was performed using independent-sample t-tests, whilst an association between each risk factor and prolonged PLOS was analysed by Chi-square tests. Multivariate analyses using stepwise multiple regression and stepwise logistic regression were used to identify risk factors that had an independent effect on PLOS and prolonged PLOS, respectively. The study firstly derived a model using preoperative predictors, then a second model was developed to determine which postoperative risk factors also provided additional information whilst at the same time controlling for the identified preoperative factors.

PLOS ranged from four to 47 days and 37% of patients had a prolonged PLOS. By univariate analysis, the preoperative factors that significantly prolonged PLOS were: repeat procedures, CABG with valve surgery, congestive heart failure, a preoperative stay in the coronary care unit, a preoperative length of stay greater than eight days, emergency surgery, renal failure, and insulin-dependent diabetes. Patients with at least one of these factors had a significantly higher incidence of a prolonged PLOS.

When multivariate analyses were applied, significant variables prolonging PLOS included repeat CABG, CABG with valve surgery, congestive heart failure, insulin-dependent diabetes, renal failure and a preoperative stay in the coronary care unit.

Disappointingly, the authors did not report the results of the multiple regression and logistic regression analyses separately and therefore it is not clear which variables predicted PLOS and prolonged PLOS respectively and this limits the usefulness of the results. The authors concluded that the presence of certain pre and postoperative factors can be used to predict prolonged PLOS after CABG but did not report the predictive performance of the models to justify this conclusion.

There are several limitations to the internal and external validity of the findings which were also not discussed by the authors. These include the retrospective approach, the use of a small convenience sample with no calculation of the adequacy of the sample size, and the use of a single centre.

The authors did not give their rationale for which variables were included in the study; so again, it is possible that important variables were not included in the analysis. Similarly, it was not discussed if the authors were the clinicians who made the decision to discharge, although the criteria for discharge were explicit. The exclusion criteria, definitions of the variables, and statistical analyses were not sufficiently explicit or comprehensive to enable replication. It is also questionable whether the data satisfied the distributional assumptions for the parametric tests described. The authors referred to a previous study of their own (Lazar et al, 1987), but no other review of pertinent literature was offered, although they did refer to the findings of Weintraub et al (1989) when discussing their results.

Whilst the study was more contemporary than Weintraub et al (1989), the limitations mentioned above cast doubt on the usefulness of the findings to the current research. However, the study did identify the potential impact that the changing profile of patients having surgery and the influence of invasive cardiology interventions may have on the variables that influence PLOS.

A much larger, multi-centre study published in the same year also included the wider population of both CABG and heart valve surgery. Tu et al (1995) reported the development and validation of a simple additive six-variable risk index to predict the risks of in-hospital mortality, prolonged intensive care unit length of stay, and prolonged PLOS after cardiac surgery. Unlike previous research, the purpose of this study was to develop an index to facilitate inter-institutional comparisons rather than cost considerations. Data was collected from a province-wide database of all nine adult cardiac surgery institutions in Ontario, Canada, for a total of 13,098 patients who underwent CABG and/or valve surgery. The study was observational and retrospective and incorporated two phases to derive and validate the index.

In the first phase, multivariate stepwise regression was used to identify risk factors that were then included in logistic regression models for mortality, prolonged intensive care unit stay, and prolonged PLOS from a derivation set of 6213 patients who had surgery during the 1991 fiscal year. Prolonged PLOS stay was defined as greater than 17 days as this corresponded to the 90^{th} percentile for this outcome in the Ontario population and was thought to reflect the development of morbidity rather than differences in discharge practices.

The variables investigated as potential risk factors were described in the study as; "age, sex, left ventricular function, type of surgery, repeat operation, recent MI, number of vessels bypassed, LMS disease, and the non-cardiac co-morbid diseases contained in the Charlson co-morbidity index (e.g. diabetes, chronic obstructive pulmonary disease, and so on)" (Tu et al, 1995: 679).

The risk factors identified were included in the logistic regression models for each outcome only if the variable was a significant predictor of that outcome at the $p < 0.05$ level and also increased the predictive performance of the model. The receiver-operating characteristic (ROC) curve was used to evaluate the performance of the model. A variable was only included if it improved the ability of the model to correctly classify patients as measured by an incremental improvement in the area under the ROC curve of ≥ 0.01. Effect size was measured using odds ratios calculated from the coefficients of the variables in the three logistic regression models, and their goodness of fit was assessed using the Hosmer-Lemeshow statistic.

The risk index was then created by rounding the mean of the three odds ratios for each risk factor in the logistic models to the nearest integer. The resulting six variables included in the index were classifications of age, sex, left ventricular function, type of surgery, urgency of surgery and repeat operation. The resulting risk index was thus designed to predict more than one outcome and applied to both CABG and valve surgery patients.

In the second phase, the risk index was tested on 6885 patients the following year to validate the model. The results showed that increasing risk index scores were associated with greater mortality rates, longer stays in the intensive care unit and longer PLOS. The overall predictive ability of the risk index and the three logistic models were assessed by calculating the area under the ROC curve in both the derivation and validation sets. The index validated well although it predicted mortality significantly better than prolonged PLOS in both the derivation and validation sets.

The authors suggested this may be because differences in patient case-mix explain variations in mortality better than they explain variations in PLOS, where other factors, such as different practice styles, were likely to play a role. The areas under the ROC curve for prolonged PLOS in the derivation and validation sets were 0.72 and 0.69 respectively.

The authors clearly described their rationale for their study in context with other databases and previous work in the field. They referred to several cardiac surgery risk models which required extensive risk factor collection and were based on complex mathematical equations, and discussed the trade off with the simplicity of the models and their statistical precision. The authors duly limited the findings of the study to Ontario, Canada. Data collection by database retrieval was limited to the variables and definitions for which the data was originally collected and assumed that the records were accurate and complete. The authors stated that missing and inconsistent data were completed or checked using other registries and/or chart reviews.

The methods were explicit and described sufficiently enough to enable replication, although the stepwise method was not reported. The description of which variables were included in the study however was not clear and there were no definitions given. Similarly, the rationale for the variables studied as potential risk factors for inclusion in the index was not given so it is possible that important variables may not have been included in the analysis.

The authors compared their results with other registries and databases and described their validation methods in detail. They also offered alternative explanations for their findings and volunteered that other models may provide more precise stratification of risk at the individual patient level. Again, as with Lazar et al (1995) funding policies and resources seemed to be a major motivation and application for the study. It was also acknowledged that surgical outcomes improve over time and that the risk score levels were determined annually to reflect temporal improvements in the quality of surgical care.

4.1.2 STUDIES IN THE UNITED KINGDOM

American hospitals tend to be subject to pressures from insurers or hospital administrators to reduce costs by discharging patients swiftly whilst other pressures such as shortage of beds and staff tend to influence discharge practices in the UK. Consequently, the applicability of the North American research findings to the UK population is questionable.

An attempted modelling of PLOS by Mounsey et al (1995) in the UK was not successful. This study had some serious flaws. Mounsey et al (1995) prospectively audited the records of 431 consecutive patients who underwent CABG at a single UK centre over a nine-month period. In order to maximise cardiac surgical capacity, the study attempted to prospectively identify fast track patients (defined as those who occupy an intensive care unit bed for less than 24 hours) and patients likely to have a short postoperative stay (defined as less than seven days).

A total of 20 variables were investigated; age, gender, smoking, BMI, diabetes, hypertension, chronic obstructive airways disease, renal failure, angina grade, exercise tolerance, MI, number of diseased vessels, LMS disease, ejection fraction, left ventricular end-diastolic pressure, number of vessels bypassed, use of internal mammary artery (IMA), bypass time, urgency of operation, and previous operation.

A univariate analysis was performed in which continuous variables were analysed by t-tests and dichotomised variables were analysed by the Chi-square test. Stepwise logistic regression was used for multivariate analysis.

The authors found that variables affecting length of stay in the intensive care unit and PLOS within seven days were different. Several factors were weakly predictive of a short stay in hospital by univariate analysis. A total of 24% spent seven days or less in hospital after surgery, these were significantly younger ($P<0.001$) with lower incidence of previous MI (positive predictive accuracy 30%, sensitivity 53%), were less likely to have chronic obstructive pulmonary disease (25%, 98%), and more likely to have one or two vessel disease (33%, 41%). They were also more likely to have an IMA conduit (27%, 89%), and more likely to need fewer than three distal anastomoses of the vein graft (29%, 63%).

Sex, obesity, diabetes, hypertension, unstable angina, renal function, left ventricular function, emergency or elective operation, and re-operation were not associated with PLOS. By multivariate analysis, only age and the time spent on bypass were significantly predictive of PLOS. However, no factor was of sufficient predictive value to satisfactorily model PLOS on the basis of the criteria tested in this study. Only the absence of chronic obstructive pulmonary disease and the use of an IMA were of useful sensitivity. Consequently, modelling of PLOS within seven days was not attempted.

The authors clearly stated the aims and purpose of the study, but the findings are limited by the use of a small convenience sample from a single centre. The authors reported the study to be a prospective one but the methods of data collection described were not clear and appear to have been more retrospective in nature. There was also no detail of any exclusion criteria so it was not clear if the sample included patients undergoing concomitant valve surgery.

The inclusion and definitions of the variables investigated were explicit but the rationale for those which were included was not given. The statistical techniques used were not described with sufficent comprehensiveness to enable replication of the study. Measures to eliminate bias in the treatment of patients identified as fast track and whether the authors were involved in the decision to discharge was not discussed. Unfortunately, the multivariate analysis of PLOS within seven days was not attempted based on the results of the univariate analysis. However, the authors did not discuss the possibility that by dichotomising many of the variables, much of the detail was lost and the groups therefore became too broad an approximation which may have accounted for the lack of predictive value. The authors discussed the limited generalisability of their findings but did compare them to previous work.

4.1.3 INVESTIGATIONS OF THE INFLUENCE OF SPECIFIC VARIABLES ON POSTOPERATIVE LENGTH OF STAY

The next two studies include multivariate analyses of PLOS as part of larger analyses to assess the influence of age and gender respectively on clinical outcomes after CABG. Whilst not primarily focused upon developing models to predict PLOS, the studies provide further evidence of the demographic and physiological variables that are predictive of PLOS after CABG.

Paone et al (1998) focused on the outcomes of a clinical pathway with regard to the elderly population. The aim of the study was to investigate whether age limited the effectiveness of a five-day postoperative pathway after CABG, one year after its introduction in a single American hospital.

Data was retrospectively collected from a computerised database for 445 consecutive patients who underwent isolated CABG with CPB over a 13-month period between 1996 and 1997 in order to determine whether the benefits of the clinical pathway were comparable for younger and older patients. All patients were treated with the intention of passing through the same clinical pathway with discharge on the fifth postoperative day.

The study included a univariate and multivariate analysis of the relationships between PLOS and the following preoperative variables: age, gender, BSA, diabetes, hypertension, chronic obstructive pulmonary disease, creatinine level, cerebrovascular disease, previous MI, urgency of surgery, indications for surgery, congestive heart failure, preoperative heparin, intravenous nitrates, previous angioplasty, LMS disease, triple vessel disease, intra-aortic balloon pump, and ejection fraction.

Univariate analysis of the preoperative variables identified associations between PLOS and age, gender, BSA, diabetes, hypertension, chronic obstructive pulmonary disease, creatinine level, cerebrovascular disease, previous MI, indications for surgery, congestive heart failure, intravenous nitrates, triple vessel disease, and preoperative intra-aortic balloon pump ($p < 0.05$). Multivariate analysis of preoperative variables using Cox's proportional hazard regression, identified age along with female gender, hypertension, chronic obstructive pulmonary disease and BSA as significantly predictive of PLOS. However, when postoperative variables found to be different by univariate analysis were added to the model, only age remained marginally significant whilst blood transfusion, intra-aortic balloon pump use, pneumonia and atrial fibrillation were the strongest predictors of increased PLOS. The model was not evaluated in more detail.

The investigation of the effect of age on PLOS was examined in more detail. The results showed that PLOS was significantly less for younger patients, and twice as many younger patients were discharged within five days of surgery. Of those over 70 years old, 34% were discharged within five days, 64% within seven days and 82% within ten days compared with 64%, 85% and 93% of those less than 70 years old ($p < 0.001$).

However, the two age groups were not comparable at baseline. The elderly were more likely to be female, have a smaller BSA, a higher incidence of cerebrovascular disease, congestive heart failure, three vessel disease, and an ejection fraction less than or equal to 40%. Analysis of perioperative and postoperative data also revealed differences between the two groups. The mortality rate was higher for the elderly group who also had longer CPB times, were less likely to receive IMA grafts and more likely to receive a blood transfusion or suffer a complication during the postoperative period.

Only the incidence of atrial fibrillation was found to be significantly different between the two groups which resulted in comparable prolongations of PLOS for both older and younger patients. The authors found a three-fold increase in the incidence of atrial fibrillation in the elderly and concluded that increased PLOS is largely attributable to the increased incidence of atrial fibrillation which is the most potentially modifiable factor in delaying discharge.

The authors concluded from their data that age is an immutable factor that contributes to prolongation of the hospital stay after CABG but modification of a uniform pathway is not needed to reasonably limit the PLOS of elderly patients. The results of the study fit with previous evidence and the authors compared their results to previous study findings, thus adding to the body of evidence associating age with PLOS.

The findings are however limited by the retrospective analysis of data retrieved from a large database, and the use of a small convenience sample from a single centre population. Issues of generalisability were not addressed in the report and it is not known if the sample was representative of the given population.

The selection of statistical tests was clearly articulated but not justified and it was not stated if the distributional requirements of the tests were met. Furthermore, descriptive analysis showed that the two groups were not comparable at baseline but the authors did not report if any methods were used to control for confounding variables in the analyses. Similarly the authors did not discuss alternative explanations for their findings.

In a similar study, Aldea et al (1999) investigated the effect of gender on outcomes including PLOS after CABG surgery. Multivariate analyses were performed to assess whether gender directly and independently influenced clinical outcomes or did so through other associated preoperative and intraoperative variables.

The authors analysed prospectively collected data for 1,743 consecutive patients undergoing first time CABG, at a single centre in America, between 1994 and 1997. Data was retrieved from the Society of Thoracic Surgeons (STS) National Cardiac Surgery Database registry for the following preoperative variables: age, gender, diabetes, obesity, hypertension, hypercholesterolemia, renal dysfunction, carotid vascular disease, previous cerebral vascular accident or transischaemic attack, previous MI, smoking, chronic obstructive pulmonary disease, PVD, congestive heart failure, ejection fraction, BSA, haematocrit, number of diseased coronary arteries, LMS disease, preoperative use of intra-aortic balloon pump, aspirin, intravenous nitrates, and intravenous heparin, urgency of surgery, dyspnoea and STS mortality risk.

Multivariate linear regression was used to determine the important predictors of PLOS, using a backward elimination procedure, although always including gender in the model. Independent preoperative and intraoperative variables that influenced PLOS were female gender, previous cerebral vascular accident/transischaemic attack, hypertension, chronic obstructive pulmonary disease, non-elective CABG, pre-operative renal dysfunction, age, and cardiopulmonary pump time. Not found to be significant were previous MI, diabetes, ejection fraction, PVD, LMS disease, and cross-clamp time.

Unfortunately the model was not evaluated any further.

A more detailed analysis of gender by the authors, illustrated confounding relationships with other variables which may offer alternative explanations for the impact of gender on PLOS. Women comprised 30% of patients in the study, were older, and had more urgent surgical interventions, a higher incidence of diabetes, hypertension, and lower BSA. Women also received fewer arterial grafts, were less likely to receive internal thoracic artery grafts, and had fewer vessels bypassed but had similar cross-clamp times per vessel bypassed.

The primary focus of this study was to compare gender and selected outcomes after CABG surgery. However, the multivariate analysis of PLOS adds to the body of literature predicting PLOS after cardiac surgery by identifying which preoperative variables were found to be predictive of PLOS.

Similar to previous studies, the findings are limited by the retrospective secondary analysis of prospectively collected data retrieved from a large database, and the use of a small convenience sample from a single centre population. The limitations of the internal and external validity of the findings were not discussed by the authors and it is not known if the sample was representative of the given population.

4.1.4 STUDIES THAT COMPARE HOSPITALS

As benchmarking and inter-hospital comparisons have become commonplace in cardiac surgery, PLOS has received particular attention in order to compare hospital resource use. The next two studies use hospital comparison data to investigate the influence of hospital variability on PLOS in addition to patient variables. The findings suggest that PLOS is strongly influenced by variation within and between hospitals.

Rosen et al (1999) aimed to identify the major clinical predictors of PLOS after isolated CABG and to assess the degree to which patient characteristics accounted for variations in PLOS between hospitals.

A convenience sample of 3605 patients aged over 64 years undergoing CABG at 28 hospitals in two US states over a nine-month period was utilised. Data was collected for secondary analysis using the pilot Cooperative Cardiovascular Project database.

Variables were included based on their clinical importance in predicting PLOS according to the findings from previous research (Weintraub et al, 1989; Lahey et al, 1992; Lazar et al, 1995) or mortality. Both preoperative variables and postoperative complications were included for analysis. However, the actual number and definitions of the variables used was not reported.

Univariate predictors of log-transformed PLOS were identified by simple linear regression. The reporting of significant univariate predictors was incomplete. Those stated in the report were; increasing age, female gender, chronic obstructive pulmonary disease, congestive heart failure, cardiovascular disease, renal function, preoperative intra-aortic balloon pump, MI, diabetes, PVD, and decreased ejection fraction.

The univariate variables found to be significant were then used in the multivariate analyses, using stepwise linear regression. Models were then constructed using preoperative variables and also postoperative complications. Data for patients who died after surgery were excluded from the analysis. Twelve multivariate predictors of PLOS were identified, namely; increasing age, female gender, chronic obstructive pulmonary disease, congestive heart failure, cardiovascular disease, renal dysfunction, intra-aortic balloon pump, MI, diabetes, and PVD. However, only 9% of the variation in PLOS could be explained by preoperative clinical factors.

A predicted PLOS was derived for each patient based on the multivariate model and a risk adjusted PLOS calculated for hospital comparisons using the general linear model. Hospital characteristics explained 7.5% of the variability in PLOS. Analysis of variance (ANOVA) was used to compare PLOS between hospitals while controlling for significant patient risk factors. The hospitals varied significantly in their unadjusted PLOS, which persisted despite adjustment for preoperative patient characteristics.

Unfortunately, the differences between the hospitals, for example size, teaching status, number of operations performed, which may have influenced patient discharge were not identified. Possible reasons for the variation in PLOS between hospitals were broadly referred to as being differences in the quality and efficiency of care.

Rosen et al (1999) clearly stated the aims and rationale for the study, and placed their work within the context of previous work suggesting that PLOS varies widely between hospitals. The study has the benefit of a large sample size derived from multiple centres but despite the increased statistical power, the findings are limited by the use of a convenience sample of patients over 64 years old at hospitals within two US states.

The inclusion and exclusion criteria were explicit but the secondary analysis of data from a large database is limited to the variables and definitions for which the data was originally collected and assumed the records were accurate and complete. Although the variables included were based on their demonstrated importance in predicting PLOS in previous studies as well as mortality data, they were not clearly stated or defined. The authors acknowledged the possibility that not all important variables were included for analysis and it is also evident that as with previous research potentially important variables were omitted.

The reporting of univariate predictors of PLOS was incomplete and the use of linear regression to non-linear or log transformed PLOS has been questioned (Austin et al, 2002). Consequently, questionable inferences may have been drawn from the models developed which also lacked prospective validation on another data set.

The findings of the study were comparable to previous research predicting PLOS and between hospital variability in PLOS. The authors recommended further research to determine the practice patterns within hospitals that contribute to variations in PLOS after CABG and suggest the potential for increasing efficiency at certain hospitals.

Another US study adds to the findings of Rosen et al (1999). Peterson et al (2002) investigated the degree to which hospital variables influenced PLOS beyond patient variables. As part of a benchmarking of institutional performance, the authors explored the magnitude of hospital variability in PLOS in order to determine the degree to which this variability was accounted for by differences in patient case-mix. In addition to comparing the degree to which hospitals varied in PLOS after adjusting for patient case-mix, the analysis also investigated the degree to which PLOS was affected by preoperative patient factors, and developed and validated three models estimating the likelihood for early discharge (within five days), prolonged PLOS (more than 14 days), and overall PLOS.

The observational study re-analysed 496,797 isolated CABG procedures between 1997 and 1999 at 587 US hospitals participating in the STS National Cardiac Database. The database was established in 1989 to assess and compare cardiothoracic surgical outcomes with data collected from hospitals representing 60% of all US hospitals performing CABG. The sample was randomly divided into a model development set (80%) and a validation set (20%).

Variables were selected for analysis based on their prior relationship to procedural mortality or morbidity within the literature, although the actual variables included were neither stated nor defined. Univariate analysis of the variables and their association with the three outcomes were performed. All variables with a significant univariate relationship to PLOS ($p < 0.05$) were included in the multivariate analysis. Multivariate models were developed for each outcome using a multi-step process. Stepwise logistic and linear regression were used to identify 25 independent preoperative factors affecting a patient's likelihood for early discharge, prolonged stay, and overall log transformed PLOS.

Model performance was assessed by a number of criteria in both the development and validation populations. Hierarchical logistic regression models were used to determine the degree to which the random effects of hospital factors influenced PLOS beyond patient factors. The relative influence of hospital versus patient characteristics was compared by estimating the ratio of reduction in variation using patient risk factors only to that obtained from the mixed effects model.

The results showed that 53% of patients were discharged within five days, whilst 5% required more than 14 days. Similar to the findings of previous studies, the major factors affecting measures of PLOS included age, gender, prior surgery, disease severity, and co-morbid illness. Relative to those with longer PLOS, those discharged within five days of surgery tended to be male, younger, had less acute presentations, and lacked co-morbid illness. PLOS was significantly associated with increasing preoperative mortality risk groups based on the STS CABG mortality risk score. However, even after adjustment for case-mix, there remained wide unexplained variability among hospitals in PLOS

The multivariate predictors of a patient's likelihood for early discharge, prolonged discharge and PLOS as a continuous variable included age, BSA, gender, ethnicity, congestive heart failure, dyspnoea classification, chronic lung disease, smoking, hypertension, stroke, diabetes, vascular disease, renal failure, hypercholesterolemia, aortic stenosis, mitral insufficiency, severity of disease, ejection fraction, LMS disease, previous MI, repeat surgery, and urgency of operation. The early and prolonged discharge models validated well, but the preoperative variables could only explain a minor proportion of the variability in PLOS.

The ability of the models to predict PLOS at the individual patient level was limited since preoperative factors were not the major forces determining

PLOS when compared to hospital, surgeon, and chance events. The inclusion of the hospital where surgery was performed improved the predictive power of the models. Knowing the hospital of surgery accounted for approximately 40% of the explained variation in early discharge, 27% for prolonged stay, and 36% of PLOS as a continuous variable.

Again, with the exception of the surgeon, the hospital characteristics which may have influenced PLOS were not identified but differences in the quality and efficiency of care were again suggested. The study did find that the identity of the surgeon clinically responsible for the patient's care did have an influence upon PLOS. This influence and the possible reasons behind it were not discussed in further depth.

The results also showed that hospitals that were more likely to have patients with prolonged stays tended to have higher risk-adjusted operative mortality, whilst there was no association between a hospital's likelihood for early discharge and their risk adjusted operative mortality. The authors suggested that their findings indicated that the factors influencing early discharge may be different for those that predict prolonged stays, where prolonged stays indicate the occurrence of a postoperative complication, which is linked to mortality risk factors, while short stays are more susceptible to provider effect.

The large sample size of this multi-centre study allowed a large number of clinical risk factors to be investigated. The author's claim this was reflected in the better predictive performance of their model compared to previous models. However, the exact variables included in the original univariate analysis were not clearly stated and were limited to mortality and morbidity data.

The findings are also limited by the retrospective re-analysis of data collected for a large database. The authors reported that less than 2% of patients were excluded because data relating to age, gender, and dates of surgery or discharge was missing.

The definitions and statistical methods were explicit and sufficiently comprehensive to enable replication of the study, although the use of linear regression on log-transformed PLOS has been questioned (Austin et al, 2002). Unfortunately, the authors did not report the variables predictive of each PLOS outcome individually, so it is not known how the variables of predictive value differed between the three PLOS outcomes.

The authors offered a comprehensive comparison of their findings with previous research and acknowledged the arbitrary nature of the cut-points of early and prolonged discharge which reflected practice at that time. Application of the findings was limited to contemporary national benchmarking information on PLOS in the US.

The findings of these two studies are supported by Ghali et al, (1999), Butterworth et al (2000) and Johnson et al (2004) who also concluded that a large proportion of the variation in PLOS after CABG surgery is explained by hospital factors which may reflect differences in the quality and efficiency of care provided, use of discharge protocols, clinician practice patterns, and hospital culture.

However, the actual differences between and within hospitals that influence PLOS after cardiac surgery have yet to be fully identified and investigated beyond the identity of the surgeon in the current multivariate literature.

4.1.5 THE RESEARCH DESIGNS USED IN THE KEY PAPERS

Several researchers have investigated the multivariate prediction of either short-stay, prolonged stay, and/or PLOS as a continuous variable after cardiac surgery in the adult population. Either cost considerations or hospital comparisons provide the motivation for research in this field.

The level of measurement for PLOS and the cut-off points for short and prolonged stay that are chosen for investigation tend to be determined by the motivation for the study and the healthcare system studied, particularly the mode of reimbursement used within the healthcare system. Such differences must be considered when comparing the methods and findings of the studies reviewed and the implications for the current study.

All the studies reviewed are observational. Both retrospective (Lazar et al, 1995; Tu et al, 1995; Paone et al, 1998; Aldea et al, 1999; Rosen et al, 1999; Peterson, et al, 2002) and prospective (Weintraub et al, 1989, Mounsey et al, 1995) data collection methods have been used.

In general, retrospective designs appear to produce less convincing evidence about causal relationships between the variables than prospective designs; they are however valuable in establishing a relationship between variables (Robson, 1993). This is particularly so if retrospective analyses have enabled data to be collected from large sample sizes with increased statistical power. Retrospective data may not be as reliable as data collected prospectively as it relies on the accuracy and completeness of previously collected data. It is also limited to patients that have already been discharged, an endpoint defined by past decisions. However, in all the studies considered in this section, it is not clear what role, if any, the researchers played in the decision to discharge a patient and what measures were in place to avoid bias in this respect.

All the studies reviewed use convenience samples, which are readily accessible subgroups of the population. These are often limited to a single centre meaning that the findings potentially lack generalisability to other settings. The studies reviewed are dominated by research in the US and the results may therefore be sensitive to the healthcare system studied and its mode of reimbursement. A previous attempt to model PLOS in the UK was not successful and this area remains under-researched in the UK.

Only three studies use large samples selected from multiple centres (Tu et al, 1995; Rosen et al, 1999; Peterson et al, 2002). Most studies are based on one or two centres (Weintraub et al, 1989; Lazar et al, 1995; Mounsey et al, 1995; Paone et al, 1998; Aldea et al, 1999) and the findings may therefore have limited application to the general population.

Studies with larger sample sizes tend to generate secondary analyses of mortality and morbidity data from large databases (Tu et al, 1995; Aldea et al, 1999; Rosen et al; 1999; Peterson et al, 2002). Data collected is limited to the variables and definitions for which the data was originally collected and assumes the records are accurate and complete. It is possible that important variables have not been included in analyses using only data retrieved from the databases. Such databases rarely include psychosocial variables and researchers have not considered including these variables in multivariate analyses. Consequently, a gap in knowledge remains regarding the effect of psychosocial variables on PLOS.

The variables in the predictive models and the size of their coefficients are dependent on the data sets used. The variables included in both univariate and multivariate analyses are often not well reported by the researchers. The models also lack prospective validation using other data sets in different settings and are not under-pinned by theory.

Psychosocial variables have rarely been included in multivariate analyses of PLOS. Where these variables have been included, they have usually been entered into the modelling process after demographic and physiological variables and their additional predictive value investigated. These studies are discussed section 4.2.

4.1.6 THE FINDINGS OF THE KEY PAPERS

Most authors have identified the changing profile of patients having surgery and changes to postoperative management over time and suggested that the variables that influence PLOS are also likely change over time. Hence, the studies represent a snapshot of the situation and the heterogeneity of the population must be taken into account when comparing research findings over time.

Variations in the characteristics of the CABG population over time and between hospitals, together with variations in practice all have important implications for the interpretation of research literature from different time periods and populations, rendering comparisons between studies problematic.

Given the limitations imposed by the research designs and samples, the findings generally suggest that the variables associated with, or predictive of, either a short or prolonged PLOS are different. Analysis of hospital comparison data suggests that a short-stay after cardiac surgery tends to suggest the absence of a postoperative complication and appears to be more susceptible to the provider effect (Peterson, 2002). In contrast, prolonged PLOS tends to suggest the occurrence of a complication and is associated with risk factors that are predictive of mortality (Weintraub et al, 1989; Lahey et al, 1992; Lazar et al, 1995; Tu et al, 1995; Peterson et al, 2002).

The prediction of PLOS as a continuous variable appears to be the most elusive area for all the studies. PLOS has a complex distribution which is positively skewed and difficult to incorporate into a parametric model. The choice of statistical model may result in different conclusions about the impact of patient characteristics to predict PLOS. The studies described in this section use different statistical strategies to model PLOS as a continuous variable. There is no uniformly agreed statistical framework in which to analyse PLOS and the significance of the association between PLOS and preoperative variables reported in the studies are in part due to the statistical model chosen (Austin et al, 2002).

Several preoperative variables have consistently been found, in varying degrees of statistical significance, to be of predictive value to short-stay, prolonged stay or PLOS as a continuous variable after CABG over multiple and diverse settings (Table 4.1.1). These include, age, gender, urgency of surgery, ejection fraction, repeat or combined surgery, renal function, diabetes, and pulmonary disease.

Table 4.1.2 summarises the research designs, samples, statistical methods and main findings of the key papers reviewed in this section.

However, it appears that these demographical, physiological and procedural variables can explain only a small amount of the variability in PLOS. The failure to include psychosocial variables in multivariate analyses means that psychosocial data which may add significant and clinically meaningful information to models predicting PLOS after CABG is relatively unexplored.

Whilst there are implications for both cost and convenience, the preoperative collection of psychosocial data in addition to traditional clinical data may yield information independent of physiological, demographical and procedural variables and help explain more of the variation that is left unaccounted for in existing models that include only these variables, and subsequently improve their ability to predict PLOS after CABG.

Based on the studies reviewed, it was hypothesised in the current study that PLOS and discharge within five days of surgery can be predicted using these variables together with other physiological variables identified in chapter 3 and psychosocial variables that would be known in the preoperative period.

The next section reviews the literature to identify any psychosocial variables that have been associated with PLOS after cardiac surgery by either univariate or staged-entry multivariate analysis.

TABLE 4.1.1:
VARIABLES IDENTIFIED AS PREDICTIVE OF POSTOPERATIVE LENGTH OF STAY, SHORT-STAY, AND PROLONGED STAY AFTER CARDIAC SURGERY.

Variable	PLOS	Short-stay	Prolonged stay
Age	Weintraub et al (1989) Paone et al (1998) Aldea et al (1999) Rosen et al (1999) Peterson et al 2002)		Weintraub et al (1989) Lahey et al (1992) Tu et al (1995)
Gender	Weintraub et al (1989) Paone et al (1998) Aldea et al (1999) Rosen et al (1999) Peterson et al 2002)		Weintraub et al (1989) Tu et al (1995)
Body size	Paone et al (1998) Peterson et al 2002)		Lahey et al (1992)
Diabetes	Rosen et al (1999) Peterson et al 2002)		Lazer et al (1995)
Hypertension	Paone et al (1998) Aldea et al (1999) Peterson et al 2002)		
Renal impairment	Aldea et al (1999) Rosen et al (1999) Peterson et al 2002)		Lahey et al (1992) Lazer et al (1995)
Ejection fraction	Weintraub et al (1989) Peterson et al 2002)		Weintraub et al (1989) Tu et al (1995)
Angina			Weintraub et al (1989)
LMS disease	Peterson et al 2002)		
Previous M.I.	Rosen et al (1999) Peterson et al 2002)		
Dyspnoea	Peterson et al 2002)		
Congestive heart failure	Rosen et al (1999) Peterson et al 2002)		Lahey et al (1992)
Pulmonary disease	Paone et al (1998) Aldea et al (1999) Rosen et al (1999) Peterson et al 2002)		
Raised cholesterol	Peterson et al 2002)		
Smoking	Peterson et al 2002)		
Cardiovascular disease	Aldea et al (1999) Rosen et al (1999) Peterson et al 2002)		
PVD	Rosen et al (1999)		
Urgency of surgery	Weintraub et al (1989) Aldea et al (1999) Peterson et al 2002)		Weintraub et al (1989) Tu et al (1995)
Repeat surgery	Peterson et al 2002)		Lazer et al (1995) Tu et al (1995)
Type of surgery			Tu et al (1995) Lazer et al (1995)
Preoperative stay on CCU			Lazer et al (1995)
Use of intra-aortic Balloon pump	Rosen et al (1999)		Lahey et al (1992)
CPB time	Aldea et al (1999)		
Ethnicity	Peterson et al 2002)		
Hospital		Peterson et al 2002)	

TABLE 4.1.2:
SUMMARY OF THE RESEARCH DESIGNS AND MAIN FINDINGS OF THE KEY PAPERS

Study	Design	Data Collection methods	Procedure(s) studied	Variables	Outcome Measure(s)	Multivariate Statistical Analysis	Preoperative variables of predictive value
Weintraub et al (1989). Development and validation of three (Preoperative, perioperative and combined) models to predict PLOS and prolonged PLOS	Observational Convenience sample N = 4,683 Two US hospitals	Prospective 1981-1986	First time CABG	Nine Preoperative variables plus perioperative clinical and angiographic data.	PLOS	Stepwise linear regression	Age, gender, urgency of surgery, (R^2=0.20)
					Natural log PLOS	Stepwise linear regression	Age, gender, urgency of surgery, ejection fraction (R^2=0.33)
					PLOS greater than ten days	Stepwise logistic regression	Age, gender, elective surgery, angina, and ejection fraction (R^2=0.29)
Lahey et al (1992). Measurement of preoperative predictive indicators of increased PLOS.	Observational Convenience sample N = 924 (over 60 years old) Single US hospital	Retrospective Data collection methods not stated. 1989-1990	CABG	17 preoperative variables	PLOS greater than 14 days	Cox proportional hazards model	Congestive heart failure, use of an intra-aortic balloon assist device, interaction between congestive heart failure and use of an intra-aortic balloon assist device, creatinine >2.0mg/dl, obesity and age.

Study	Design	Data Collection methods	Procedure(s) studied	Variables	Outcome Measure(s)	Multivariate Statistical Analysis	Preoperative variables of predictive value
Lazar et al (1995) Development of two (preoperative and preoperative and postoperative variables) models to predict PLOS and prolonged PLOS	Observational Convenience sample N = 194 Single US hospital	Retrospective Review of patient notes 1993	CABG Repeat CABG Valve + CABG	17 preoperative variables plus nine postoperative variables	PLOS	Stepwise multiple regression	Variables not stated. No model performance given.
					PLOS greater than seven days	Stepwise logistic regression	Repeat CABG, CABG + valve surgery, congestive heart failure, pre-operative stay on the coronary care unit, renal failure, and insulin-dependent diabetes. No model performance given.
Tu et al (1995) Development and validation of simple risk index for institutional comparisons of mortality, prolonged intensive care unit stay and prolonged PLOS	Observational Convenience sample N = 6,213 Nine Canadian hospitals	Retrospective Secondary analysis of province-wide database 1991-1992	CABG Repeat CABG CABG + valve surgery	Over 12 preoperative variables (exact number not clear)	PLOS greater than 17 days	Stepwise logistic regression	Age, gender, left ventricular function, type of surgery, urgency of surgery, and repeat operation No model performance given.

Study	Design	Data Collection methods	Procedure(s) studied	Variables	Outcome Measure(s)	Multivariate Statistical Analysis	Preoperative variables of predictive value
Mounsey et al (1995) Identification fast track patients and patients likely to have a short postoperative within seven days	Observational Convenience sample N = 431 Single UK hospital	Prospective audit	CABG Repeat CABG Not stated if valve surgery included	20 preoperative and operative variables	PLOS less than or equal to seven days	Stepwise logistic regression	Not attempted
Paone et al (1998) To investigate whether age limited the effectiveness of a five-day postoperative pathway.	Observational Convenience sample N = 445 Single US hospital	Retrospective Secondary analysis of prospective data from database 1996-1997	Isolated CABG	19 preoperative, four perioperative, and five postoperative variables.	PLOS	Cox's proportional hazard regression	Age, female gender, hypertension, chronic obstructive pulmonary disease and body surface area.

Study	Design	Data Collection methods	Procedure(s) studied	Variables	Outcome Measure(s)	Multivariate Statistical Analysis	Preoperative variables of predictive value
Aldea et al (1999) To investigate the effect of gender on postoperative outcomes and hospital stays after CABG.	Observational Convenience sample N = 1,743 Single US hospital	Secondary analysis of prospectively collected data from STS database 1994-1997	First time CABG	26 preoperative variables and six perioperative variables.	PLOS	Backward Linear regression	Female gender, previous cerebral vascular accident/transischaemic attack, hypertension, chronic obstructive pulmonary disease, non-elective CABG, pre-operative renal dysfunction, age, CPB time.
Rosen et al (1999) Identification of the major predictors of PLOS. Assessment of the degree to which patient characteristics account for hospital variations in PLOS.	Observational Convenience sample N = 3,605 (aged over 64 years) 28 US hospitals	Retrospective Secondary analysis of database. 1992-1993	Isolated CABG	Number of preoperative variables used to predict mortality and PLOS not stated Number of postoperative complications not stated Number of hospital variables not stated	Log transformed PLOS	Stepwise linear regression	Increased age, female gender, chronic obstructive pulmonary disease, congestive heart failure, cardiovascular disease, renal dysfunction, intra-aortic balloon pump, myocardial infarction, diabetes, and peripheral vascular disease. (R^2=0.09)

Study	Design	Data Collection methods	Procedure(s) studied	Variables	Outcome Measure(s)	Multivariate Statistical Analysis	Preoperative variables of predictive value
Peterson et al (2002) Development and validation of three models; early discharge, prolonged PLOS, and overall PLOS.	Observational Convenience sample N = 496,797 587 US hospitals	Retrospective Secondary analysis of database. 1997-1999	Isolated CABG	Over 25 preoperative variables Hospital variation	Log transformed PLOS	Stepwise linear regression	Age, body surface area, gender, ethnicity, congestive heart failure, dyspnoea classification, chronic lung disease, smoking, hypertension, stroke, diabetes, vascular disease, renal failure, hypercholesterolemia, aortic stenosis, mitral insufficiency, severity of disease, ejection fraction, left main stem disease, previous myocardial infarction, repeat surgery, and urgency of operation. (R^2=0.138)
					PLOS less than or equal to five days	Hierarchical stepwise logistic regression	Variables as above c-index 0.703
					PLOS greater than 14 days	Hierarchical stepwise logistic regression	Variables as above c-index 0.747

4.2 PSYCHOSOCIAL VARIABLES

Physiological, demographical and procedural variables are both easily quantifiable and objective measures, but as the literature reviewed in section 4.1 indicates, PLOS is not fully explained by these variables alone. There is some evidence that unidentified hospital characteristics, or provider variables can account for some of the remaining variance (Rosen, et al, 1999; Peterson et al, 2002). However, the role of less easily quantifiable psychosocial variables is relatively unexplored. As a result, the inclusion of psychosocial variables in addition to established variables into a multivariate regression model may yield additional information not previously captured and may also improve the ability to predict PLOS after CABG.

The studies reviewed in this section were used to identify which psychosocial variables have been associated with PLOS after cardiac surgery and may therefore assist in the prediction of PLOS by multivariate analysis. The prevalence of each of these variables within the CABG population and their interrelationship with other variables was explored with reference to the stress and coping framework in order to gain an understanding of their potential impact on, and the mechanisms through which, they may influence PLOS.

The following psychosocial variables were identified; fear and anxiety, anger, depression, optimism, social support, socioeconomic deprivation, and patient-reported health status.

4.2.1 FEAR AND ANXIETY

Anxiety has been investigated as a potential predictor of PLOS after cardiac surgery in two studies (Stengrevics et al, 1996; Oxlad et al, 2006). Anxiety is a manifestation of stress and one of the most predominant feelings expressed by preoperative CABG patients (Bengston et al, 1994; Fitsimons et al, 2000). Anxiety refers to an unpleasant emotion characterised by worry, apprehension, tension and fear (Atkinson et al, 1990: 560).

The concept of anxiety has been isolated into two constructs; state anxiety which refers to situational anxiety and trait anxiety which refers to a natural disposition toward anxiety in the individual (Speilberger et al, 1983). State anxiety levels are subject to fluctuation, whereas trait anxiety levels are regarded as relatively stable.

The intensity of anxiety a person experiences has important implications for that individual's ability to cope with a stressful situation. Normal or objective anxiety is proportionate to the threat posed and is considered adaptive, motivating the person to deal with a situation. However, neurotic anxiety is out of proportion to the threat and reduces the individuals' ability to cope.

Normal or objective anxiety can help patients prepare for surgery and reduce its stressfulness by enhancing learning and improving coping (Janis, 1958; Hayward, 1975; Boore, 1978). However, high levels of anxiety before CABG have been associated with poorer outcomes such as postoperative complications, mortality, depression and worse psychosocial adjustment (Magni et al, 1987; Pick et al, 1994; Stengrevics et al, 1996; Timberlake et al, 1997; Grossi et al, 1998; Andrew et al, 2000).

The prevalence of preoperative fear and anxiety in patients scheduled for cardiac surgery varies. Jónsdóttir and Baldursdottir (1998) reported that over half the patients they studied experienced increased anxiety whilst Underwood et al (1993) reported that 25% of their sample experienced clinically significant anxiety. Kiovula et al (2001) reported high fear in 25% and high anxiety in 5% of CABG patients. Variations in the prevalence rates reported by different studies probably reflect the use of different measurement tools and differences in the timing of assessment and the characteristics of the populations studied.

Contradictory findings have also been reported on the association of sociodemographic variables with fear and anxiety. Whilst Fitzsimons et al (2003) found no differences between state and trait anxiety with age or sex both positive and negative findings have been reported on the association of age and gender with anxiety in CABG patients by other authors.

Kiovula et al (2001) reported associations between female gender, depression, tendency toward anxiety, waiting less than four weeks for surgery, lack of vocational education, and being in employment with high fear.

Meanwhile, younger age, gender, education, marital status, employment status, depression, low pain levels and high pain levels have all been associated with high anxiety (Bengston et al, 1996; Kiovula et al, 2001). With Kiovula et al (2001) suggesting that younger patients may have high anxiety while waiting CABG because they often have rapidly advancing aggressive disease and the operation presents a threat to their career, the family's livelihood, and the patient's whole life.

Heightened anxiety and fear may be associated with poorer outcomes including delayed wound healing, longer hospital stays and higher rates of readmission (Kiecolt-Glaser et al, 1998). However, anxiety has only been examined as a predictor of PLOS in two published studies of CABG patients and was not found to be a significant variable after the adjustment of physiological, demographical and procedural variables in either study (Stengrevics et al, 1996; Oxlad et al, 2006).

Stengrevics et al (1996) investigated the relationship between state and trait anxiety and anger, and postoperative outcome in cardiac surgery patients. The authors hypothesised that high levels of state but not trait anxiety and anger would be associated with poorer outcomes including longer lengths of stay.

The Speilberger State Trait Personality Inventory (Spielberger, 1989) was used to measure state and trait anxiety and anger for 104 patients waiting for cardiac surgery at a single centre over a ten-month period. The questionnaires were completed 24 to 48 hours prior to surgery whilst data on the type of surgical procedure, preoperative length of stay, priority of surgery, gender, age and NYHA status, together with medical outcomes including PLOS, were retrospectively retrieved from patient charts.

The preoperative medical and sociodemographic variables included in the investigation were described as “factors of known prognostic significance” but no further discussion or justification for the selection of these six variables was given.

Hierarchical general linear modelling was used to assess the influence of preoperative anxiety and anger, separately and concurrently, on postoperative outcomes after controlling for the medical and sociodemographic variables. The results showed that after adjustment, preoperative state anxiety and state anger in CABG patients was significantly associated with increased postoperative complications. State anger but not state anxiety also predicted PLOS. Neither trait anxiety nor trait anger predicted complications or PLOS.

The difference in variance accounted for by the inclusion of the psychological variables in the PLOS models after medical and sociodemographic variables was not significant. The univariate influence of the psychological variables on PLOS was not investigated.

The purpose of the study was to investigate the differentiation between state and trait anxiety and anger on postoperative outcomes rather than predicting PLOS as in the current study. The subsequent discussion of the results reflected this and the authors did not discuss the results of the PLOS analysis in sufficient depth to inform the current study. Similarly, the selection of the psychological variables reflected the different focus. Only a single instrument measure was used to measure the psychological variables selected and this was not discussed or justified by the authors.

There are other limitations to this study, including the use of a convenience sample of consecutive patients undergoing cardiac surgery at a single centre, which were not discussed by the authors. Given these limitations and the differing focus of the study to the current investigation, the results suggest that neither state nor trait anxiety influence PLOS after adjustment for the relatively few medical and sociodemographic variables studied. Furthermore, models including the psychological variables studied cannot account for any further significant variance in PLOS than models containing only medical and sociodemographic variables.

Oxlad et al (2006) also found no significant association between preoperative anxiety and PLOS by either univariate or multivariate analysis. However, similar to other studies investigating preoperative anxiety, it lacked the ability to determine if anxiety was an actual preoperative condition or merely a manifestation of the prospect of imminent major surgery. This study is reviewed in section 4.2.2.

The literature review was unable to identify any previous studies which investigated fear, as a separate concept, and its influence upon PLOS.

4.2.1.1 Time on the waiting list

Several studies have focussed on the emotional reactions of patients waiting for CABG and the impact of being on a waiting list for surgery. The findings of these studies suggest that waiting for CABG is a stressor associated with fear and anxiety. Subsequently, these emotional states may have indirect influence on PLOS through an interaction with the situation/exposure variable of the time a patient waits for surgery.

The wait for CABG varies among different countries. Patients receive immediate surgery in places which have a private health care system such as America, whilst patients in countries with publicly funded health care systems such as the UK, Canada, New Zealand, Sweden, and The Netherlands have endured long waits for surgery.

However, in the UK various trends and initiatives such as Extending Choice for Patients (Department of Health, 2002a), The National Service Framework for Coronary Heart Disease (Department of Health, 2000b), and the 18 week target set out in The NHS Improvement Plan (Department of Health, 2004b) have affected both the number of people on the waiting list for CABG and changed the total time spent on the waiting list for this procedure. Currently waiting times for CABG in the UK are less than three months whilst waits of around two years were not uncommon only a few years ago. As a result of such variation in waiting times over both time and between countries it is difficult to compare studies on this subject. In addition, such studies tend to employ different measurement tools and study patients at different stages of treatment, further complicating this issue.

Generally the research in this area tends to suggest the possibility that some duration of waiting may be beneficial for patients to prepare for surgery and there may be an optimal, but as yet, unidentified waiting period for elective CABG. Koivula et al (2001) found that when the wait for surgery was less than four weeks, high fear was more common than for patients who had to wait longer than nine weeks. This finding supports previous work by Jónsdóttir and Baldursdottir (1998) who also found evidence of an optimal waiting time period, noting the trend for patients who had waited between three and four months for surgery to be emotionally worse off than patients who had waited either a shorter or longer period of time.

Kiovula et al (2001) suggested these findings confirmed the nature of fear as both a response to an immediate threat, and the cognitive component of fear; explaining that patients who have a short wait for CABG know that they have severe coronary heart disease and that high-risk patients will be operated on first.

There is a general consensus within the international literature of the adverse effects of long waits for cardiac surgery. A range of research studies from various countries collectively suggest that patients on the waiting list experience a range of difficulties including; angina and fatigue, lack of knowledge and support, anxiety, depression, unemployment and reduced income. It is possible that the longer a patient spends on the waiting list, the greater the influence these potential difficulties may have for the appraisal of the stress of the impending CABG and therefore also ultimately for PLOS itself.

A study of 68 British patients awaiting CABG found that the length of wait for surgery was significantly associated with increased anxiety and depression among patients on the waiting list, as well as impairment of work, household management, leisure time activities and family and social relationships (Underwood et al, 1993).

Similarly, Mulgan and Logan (1990) found that 32% patients had lost income and 20% claimed financial hardship while waiting for CABG surgery in New Zealand, although they did not establish any correlation between time on the waiting list and state trait anxiety scores. A Swedish study by Bengston et al (1994) showed that the duration of waiting time for CABG was positively correlated with more nervous reactions and sleeping disorders and a Canadian study by Teo et al (1998) found that 87.5% felt their quality of life had deteriorated with a negative impact on employment and income, physical stress, social support, frustration, and quality of life, whilst they were waiting for CABG.

These findings are supported by Sampalis et al (2001) who prospectively studied a cohort of 266 patients to evaluate the effects of a prolonged waiting time on the quality of life of patients before and after CABG using the Medical Outcomes Study 36-item Short-Form (SF-36) (Ware and Sherbourne, 1992). Canadian waiting lists varied from three to nine months at the time of the study and whilst there was no difference in the quality of life at baseline, it was found that immediately before surgery, those who waited more than 97 days for elective CABG had significantly reduced physical functioning, reduced vitality, reduced social functioning and general health than those waiting 97 days or less.

At six months after surgery, those who had waited longer for CABG also had reduced physical functioning, physical role, vitality, mental health, and general health. Furthermore, the incidence of postoperative adverse events was significantly greater among patients with longer waits, and longer waits were also associated with increased likelihood of not returning to work after CABG.

These findings suggest that the length of wait for CABG is important for both the physical and emotional well-being of patients and that there may also be a possible interaction with age and gender. It has been postulated that a large portion of the fear and anxiety experienced by patients and families awaiting CABG in publicly funded health care systems is directly related to the uncertainty associated with the waiting period (Pieper et al, 1985; Brenner, 1993; Bengston et al, 1996; Crisp et al, 1996; Jónsdóttir and Baldursdottir, 1998; Bengston et al, 2000; Fitzsimons et al, 2000; Screeche-Powell and Owen, 2003).

Several qualitative studies have identified uncertainty as a major source of anxiety during the waiting period. Irvin (2001) used concept analysis and Lazarus and Folkman's (1984) stress, appraisal and coping model as a framework to develop a clear conceptual understanding and comprehensive definition of the phenomenon of waiting. Waiting was defined as a "stationary, yet dynamic, and unspecified time-frame phenomenon in which manifestations of uncertainty regarding personal outcomes remain in suspension for a limited time, but for the definite purpose of something expected" (Irvin, 2001: 128). This study concluded that the critical attributes of uncertainty and loss of control constituted meaningful properties of waiting. Meanwhile, the powerlessness associated with waiting was manifested as fear, anger and the inability to concentrate.

Similar conclusions have been reached from several studies attempting to identify the major sources of anxiety of those on the waiting list. In a study of 21 CABG patients and their partners waiting for CABG in hospital, Bradley and Williams (1990) found one of the highest ranked threats for patients was the feeling of lack of personal control. This study concluded that patients indicated a need for knowledge of their disease and preoperative instruction whilst the main concerns for family members were related to information seeking.

Fitzsimons et al (2000) drew similar conclusions from their prospective investigation of the experience of waiting for CABG from a qualitative perspective. A longitudinal inductive research approach was used to conduct interviews with 70 randomly selected patients in Northern Ireland at referral for surgery, after waiting six months, and after waiting one year. Thematic content analysis identified three central themes; uncertainty, chest pain, and anxiety. Six secondary themes identified were; powerlessness, dissatisfaction with treatment, anger/frustration, physical incapacity, reduced self-esteem, and altered family and social relationships.

Participants expressed dissatisfaction at having to wait and anger that they were not given adequate information about the timing of their surgery. The authors strongly suggested that patients awaiting CABG require more information regarding the waiting time, and that nursing intervention and support should also be directed towards reducing patients' anxiety levels.

A further prospective study, by the same authors indicated that uncertainty remained a major source of anxiety. Fitzsimons et al (2003), studied the nature and intensity of anxiety felt by a randomly selected cross-section of 70 patients awaiting CABG at two hospitals in Northern Ireland, using a qualitative interview and the state trait anxiety inventory. Participants were contacted within four weeks of referral for surgery and cited five main sources of anxiety: chest pain, uncertainty, fear of the operation, physical incapacity, and dissatisfaction with care.

The results of quantitative analysis showed no significant differences by age or sex of participants and state or trait anxiety scores. There was a strong association between anxiety and angina, and a significant difference in state anxiety scores in relation to changes in income level since going on the waiting list.

Given the general consensus, in the above studies, that the time spent on the waiting list is a significant stressor for CABG patients; it is hypothesised that this situational/exposure variable will also influence PLOS via the appraisal process and the subsequent selection of coping strategies. Marital and employment status also appear relevant to this process and are therefore also hypothesised to influence PLOS too.

To summarise, the literature suggests that fear and anxiety are common within the CABG population. These emotional reactions to stress appear to interact in a complex manner with age, gender, marital status, employment and the time spent on the waiting list.

The identification of anxiety as a potential predictor of PLOS is not supported by the two studies identified from the literature search. The time a patient spends waiting for CABG is associated with fear and anxiety and may theoretically exert an influence upon PLOS by multiple pathways. The time spent on the waiting list has subsequently been identified as a potential predictor of PLOS together with marital status and employment. The influence of these person and situational/exposure variables on PLOS was therefore investigated in the current study.

4.2.2 DEPRESSION

Depression is a normal response to stress and is considered abnormal only when it is out of proportion to the event and continues past the point at which most people recover (Atkinson et al, 1990). Depression has four sets of symptoms; emotional (sadness and dejection), cognitive (negative thoughts), motivational (passivity), and physical (loss of appetite, sleep disturbance, fatigue) but not all sets of symptoms are required for a diagnosis of depression.

Depressive symptoms are common before CABG although the reported prevalence is conflicting, ranging from 20% to 47% (Burker et al, 1995; McKhann et al, 1997; Timberlake et al, 1997; Jónsdóttir and Baldeursottir, 1998; Kiovula et al, 2001; Burg et al, 2003;). Although a relatively new area of inquiry, a large and gathering body of evidence has linked depressive symptoms as an independent risk factor for outcomes such as morbidity and mortality, readmission, postoperative depression, infections, and poor wound healing after cardiac surgery (McKhann et al, 1997; Timberlake et al, 1997; Saur et al, 2001; Burg et al, 2003; Contrada et al, 2004; Doering et al, 2005).

It logically follows that if preoperative depression is linked to outcomes that may delay recovery then preoperative depression may also influence PLOS. The mechanisms to explain how depression may influence PLOS are unclear but include behavioural and pathophysiological pathways. It has been suggested that adverse behavioural changes, such as poorer hygiene, nutrition, self-care and reduced adherence to recommended health behaviours are often associated with depression and may directly increase the likelihood that patients who are depressed will have postoperative complications that in turn influence PLOS (Doering et al, 2005; Oxlad et al, 2006).

There is also evidence that both depression and anxiety directly enhance the production of proinflammatory cytokines resulting in impaired immune response to pathogens that may explain the association found between depressive symptoms, infections and impaired wound healing after CABG (Doering et al, 2005).

Cognitive theories of depression suggest that individuals prone to depression generally appraise events from a negative and self-critical perspective (Beck, 1976; Beck, Rush, Shaw and Emery, 1979; Peterson and Seligman, 1984). According to the stress and coping framework applied to the study, the way in which an individual appraises impending CABG has implications for the selection of coping strategies which may ultimately influence PLOS. Consequently, if a patient prone to depression appraises the impending CABG in a negative way then they may be less likely to select more effective problem-solving coping strategies and more likely to adopt emotion-focused strategies which in turn may increase PLOS.

The impact of preoperative depression upon PLOS after CABG does not appear to have been widely studied. Four studies investigating depression as a potential predictor of PLOS were identified from the literature search (Saur et al, 2001; Burg et al, 2003; Contrada et al, 2004; Oxlad et al; 2006). The findings of these studies are inconsistent with each other, which may reflect the use of different instruments to measure depression in the studies.

A prospective observational study by Contrada et al (2004) examined the additional influence of psychosocial variables to demographic and physiological variables in the prediction of PLOS.

The main purpose of the study was to examine religiousness as another psychosocial variable that may influence adaptation to heart surgery, where adaptation to surgery was assessed by measuring PLOS and the incidence of postoperative complications.

A convenience sample of 142 patients undergoing CABG and/or heart valve surgery between 1996 and 1998 at a single US hospital was utilised. Psychosocial interviews were conducted approximately a week before surgery to collect data on psychosocial variables (depressive symptoms, dispositional optimism, perceived social support, and trait hostility), and religiousness (religious denomination, attendance, prayers and beliefs).

Demographic data (age, gender, ethnicity, marital status, and number of years of education), and physiological data (prior heart surgery, LMS stenosis, PVD, chronic obstructive pulmonary disease, and diabetes, hypertension, smoking history, priority of surgery, anaesthesia time, and number of grafts) were derived from hospital records.

Depressive symptoms were measured as a continuous variable using the Beck Depression Inventory (BDI) (Beck et al, 1961) as a measure of cognitive, affective, behavioural, and somatic manifestations of depression. Dispositional optimism was assessed using the Life Orientation Test (Scheier et al, 1994) which measures generalised expectances for positive outcomes. To measure the degree to which patient's perceived social support was available from friends and family, the Multidimensional Scale of Perceived Social Support (Zimet at al, 1988) was used. Trait hostility and trait anger were measured using subscales of the Aggression Questionnaire (Buss and Perry, 1992).

Initial analyses were designed to identify potential predictors of both PLOS and postoperative complications, and also to determine whether psychosocial or physiological and demographic variables mediated the association of religiousness with either outcome.

Multiple regression analysis was used to identify significant predictors of PLOS. A main-effects model was constructed by entering the four sets of predictors in the following sequence: demographic variables, physiological variables, psychosocial variables, and finally religiousness variables.

The results of each step showed that the demographic variables accounted for 10.8% of the variance in PLOS. Significant effects for age and gender indicated that both older and female patients had a longer PLOS. At the second step, physiological variables accounted for an additional 8.5% of the variance and anaesthesia time had the only significant effect, with longer anaesthesia time leading to a longer PLOS.

At the third step, the psychosocial variables accounted for a further 5.8% of the variance, where the only significant effect was for depressive symptoms, with higher depression scores resulting in a longer PLOS. Perceived social support, dispositional optimism, and trait hostility were not found to be associated with PLOS. At the final step, religiousness accounted for a further 6.1% of the variance, with significant effect for attendance and beliefs. Patients who reported more attendance at religious services had longer PLOS, whilst patients with higher scores on the religious beliefs scale had a shorter PLOS suggesting that religiousness can have both positive and negative effects on PLOS.

Further analyses showed that the effects of religious beliefs were stronger among women patients and independent of physiological and psychosocial predictors. Furthermore, patients with stronger religious beliefs had fewer complications and a shorter PLOS, with the effect on complications mediating the effect on PLOS.

The findings of the study are limited by the observational design and the use of a small convenience sample from a single American hospital. However, the inclusion and exclusion criteria were explicit and the statistical methods were discussed in sufficient detail to enable replication. The authors discussed in detail the limited external validity of their sample.

The authors specifically identified the limitations imposed by their choice of variables, the measurements used and the timing of the measurements. The psychological variables selected were justified based on evidence of an association with some outcome in the cardiac population. The BDI was described as a commonly used measure of cognitive, affective, behavioural and somatic manifestations of depression and was appropriate to be used less than two weeks before surgery. However, it is not a diagnostic tool and as a self-report questionnaire the BDI is subject to a response bias.

In addition, the somatic items of the BDI such as weight loss, insomnia and loss of appetite may be present in surgical patients without necessarily being related to depression. The possibility that depressive symptoms may have reflected underlying coronary disease or other aspects of physical health was discussed.

The possibility that unmeasured variables may have contributed to longer PLOS and affected depressive symptoms were discussed as possible confounds.

The main focus of this study was to investigate the predictive value of religiousness and other psychosocial variables on PLOS and postoperative complications. However, the study did include a multivariate analysis of the predictors of PLOS after cardiac surgery that included both physiological and psychosocial variables. Whilst the stepped approach to the analysis means that demographic, physiological, and psychosocial variables were not simultaneously analysed, the psychosocial variables of depressive symptoms, religious attendance, and religious beliefs were identified as exerting an additional effect on PLOS. Whether these variables have an effect when analysed by simultaneous or stepwise regression is not known.

The findings regarding depression as a potential predictor of PLOS are supported by a more recent study. Oxlad et al (2006) recognised the paucity of research investigating the relationships between psychological functioning variables and PLOS in CABG patients and postulated that increased preoperative depression, anxiety and post traumatic stress disorder (PTSD) symptomatology would function as risk factors for longer PLOS. The authors also investigated whether these psychological risk factors remained significant contributors independent of established operative and postoperative factors.

This observational study utilised a convenience sample of 119 (85% of those eligible to participate) consecutive patients undergoing elective isolated CABG or combined CABG/valve surgery at two South Australian hospitals between April 2002 and June 2003.

Demographic data and measurement of the psychological variables of depression, anxiety, and PTSD were collected by telephone interview approximately one week after the initial outpatient appointment. Due to the lack of research investigating the impact of psychological variables on short-term outcomes and PLOS, the selection of psychological variables was based on prior research showing an association with long-term outcomes following CABG. Preoperative, operative and postoperative physiological data were extracted from medical records following surgery.

Depression and anxiety were measured using the two 14-item sub-scales of the Depression Anxiety Stress Scales (Lovibond and Lovibond, 1995). This tool was selected to measure depressive symptoms based on its brevity and reported ability to be better able to separate the constructs of depression and anxiety than other measures. PTSD was assessed using the continuous 17-item scale of the Post-traumatic Diagnostic Scale (Foa et al, 1997).

Six demographic variables that the authors stated had been previously associated with poor outcome in cardiac patients were also examined; age, gender, ethnicity, marital status, current living arrangement, and years of education completed. However, no references were given to support the selection of these variables.

Three psychiatric variables were included; self or familial history of psychiatric difficulties, and a history of exposure to traumatic event(s), assessed using the 13-item Traumatic Events Questionnaire (Vrana and Lauterbach, 1994). A further eleven medical variables were included; smoking history, previous MI, congestive heart failure, previous cardiac surgery, presence of diabetes, hypertension, hypercholesterolaemia, chronic pulmonary disease, unstable angina, and left ventricular ejection fraction.

Three preoperative variables were also included; length of wait for surgery, length of time between study assessment and surgery, and preoperative length of hospital stay. The following operative and postoperative variables were also analysed; surgical procedure, CPB time, number of grafts performed, mechanical ventilation/intubation time, and total number of perioperative and postoperative complications.

Parametric tests were used following transformations of continuous variables and multivariate associations were examined using stepped linear regression. The first model was developed by entering the demographic, physiological, psychiatric history and preoperative variables at the first step and the psychological variables (depression, anxiety, and PTSD symptomatology) at the second step.

The second model was developed by entering the demographic, physiological, psychiatric history and preoperative variables at the first step, the operative and postoperative variables at the second step, and the psychological variables at the third step.

The univariate associations between PLOS and depression, anxiety, and PTSD symptomatology were not significant, although significant relationships were identified in the multivariate analyses. In the first model, only two variables were identified as independent predictors of PLOS at the first step of the analysis (ethnicity and tobacco use) and accounted for 8% of the variance. Entry of psychological variables at the second step accounted for an additional 5% of the variance, with a higher level of depression and PTSD symptomatology significantly associated with a longer PLOS.

In the second model, variables entered at the first step accounted for 8% of the variance, operative and postoperative variables entered at the second step accounted for an additional 24.5% of the variance. Entry of the psychological variables at the third step accounted for a further 4.4% of the variance, with higher levels of preoperative depression and a lower PTSD symptomatology predictive of longer PLOS.

The authors commented that the non-significant univariate associations and significant multivariate associations between PLOS and preoperative depression score and PTSD symptomatology suggest that the relationships between the psychological and other variables studied are complex. The finding that demographic, physiological and operative/postoperative variables accounted for a large proportion of the variance and appeared to exert the greatest influence on PLOS is consistent with previous research.

The authors concluded that while PLOS is largely determined by these variables, psychological variables also influenced this outcome. However, due to the stepped approach to the modelling analysis, it is not known what percentage of the variance was accounted for when only the psychological variables were entered, or if any of the psychological variables would have been identified as significant predictors of PLOS if entered simultaneously into the model with the other variables studied.

As a consequence of the stepped modelling approach, the stated primary objective of the study to investigate preoperative psychological functioning variables as risk factors for longer PLOS following CABG appears to have been insufficient to answer the research question and was conducted on a sample that included other procedures.

The external validity of the findings of the study is limited due to the use of a small convenience sample from two hospitals. However, the inclusion and exclusion criteria were explicit, the statistical methods were described in sufficient detail, and the variables studied were unusually well reported.

The authors acknowledged the limitations of the self-report measures used, the timing of measurement, and that the small sample size may have resulted in insufficient power to detect some relationships, and justified their findings accordingly.

The principal clinical value of the Depression Anxiety Stress Scales used is to determine the locus of emotional disturbance between these three negative emotional states, although each construct can be measured separately. It is not a diagnostic tool with the scores for each construct being dimensional rather than categorical and the clinical cut-off points being arbitrary. The authors justified the use of this tool to measure depression rather than a diagnostic interview arguing that self-report measures are frequently used to assess depression in the cardiac population with good result.

The timing of the psychological measures ranged from two to 276 days prior to surgery. As the Depression Anxiety Stress Scale is designed to measure varying emotional states in the last week rather than enduring traits, this may have affected the results. However, further analyses controlling for the length of time between assessment and surgery suggested there was no impact of this variability on outcome.

The authors compared their findings with previous research and concluded that further research was required to replicate their findings and to determine the mechanisms through which the variables studied may act.

Work by other researchers does not support evidence of a statistical association between preoperative depression and PLOS (Saur et al, 2001; Burg et al, 2003).

Saur et al (2001) investigated whether or not the outcomes of PLOS, mortality and readmission were related to a patient’s level of depressive symptoms before and after CABG, after clinical factors were adjusted for. Depression was selected as a variable for investigation based an emerging body of evidence linking depression with outcomes in patients with cardiac disease.

This observational, longitudinal study used a convenience sample of 416 CABG-only patients who had preoperatively completed the Medical Outcomes Study 36-item short-form health survey (SF-36) over 21 month period between 1993 and 1995 at a single American hospital. The SF-36 includes a five-item Mental Health scale of the four mental health dimensions: anxiety, depression, loss of behavioural emotional control, and psychological well-being. Only the responses to two questions relating to depressive symptoms in the last four weeks and the overall Mental Health scale summary score were analysed in the study.

The study involved a secondary analysis of data prospectively collected and recorded for a larger quality initiative which probably explains why the SF-36 was used to assess depression rather than a specific screening tool. The relationship between the presence of depressive symptoms before CABG and PLOS was examined using log-transformed linear regression and logistic regression for PLOS of six days or longer. For both models baseline characteristics were accounted for by using the Hannan logistic risk score, an index of risk of operative mortality developed in New York on the basis of CABG operations from 1989 to 1992, accounting for age, sex, co-morbidity, severity of disease and previous cardiac surgery.

Depressive symptoms were reported in 10-11% of the sample which is less than that reported by other studies using specific depression screening or diagnostic instruments. The authors found no relationship between depressive symptoms before CABG and PLOS.

Whilst the research questions were clearly articulated by the authors and the inclusion and exclusion criteria were explicit, the sample only represented 416 patients out of a potential 2677 patients who had completed the SF-36 at admission before CABG during the study period. The authors assessed the representativeness of this sample in terms of the mortality risk which was reported to be the same as those who did not complete the questionnaire.

The findings are clearly limited by the use of a small convenience sample from a single hospital. The authors acknowledged that the analysis of secondary data was also a limitation of the study. The authors adequately described and commented on the validity of the SF-36 as a generic measure of patient's self-assessments of behavioural functioning, well-being and health status (Ware and Sherbourne, 1992; McHorney et al, 1993; Ware et al, 1993).

Both the Mental Health scale and summary score have been shown to be useful in screening for psychiatric disorders (Ware et al, 1994). However, the selection of the Mental Health summary score and the two questions relating to depressive symptoms to measure depression rather than a specific depression screening or diagnostic instrument was neither discussed nor justified by the authors. The rationale is likely to be due to the fact that this data had conveniently been previously collected for another purpose and was therefore readily available at no extra cost. This study has been criticised by Oxlad et al (2006) due to the method of measuring depression using median scores of only two items.

As a specific depression screening or diagnostic instrument was not used, the authors did acknowledge that the actual presence of depressive disorders in the study population was not known and, as a result, they were unable to examine the sensitivity and specificity of the two questions relating to depressive symptoms. Again, the discussion of the findings was limited and somewhat selective with the non significant finding regarding PLOS and depressive symptoms not being discussed.

These non significant findings are supported by Burg et al (2003) who investigated the independent contribution of preoperative depression to various short-term medical outcomes, including PLOS. A convenience sample of 89 male veterans undergoing elective isolated CABG during a one year period between 1996 and 1997 at a single American hospital was used. Depression was measured using the BDI within one week prior to surgery.

The study population was then dichotomised on the basis of clinically significant symptoms of depression, defined as a BDI of ten or more. A prediction model was first developed for each outcome studied, including PLOS, based on the following medical, surgical, and psychosocial variables using stepwise general linear regression; age, marital status, years of education, employment status, ejection fraction, urgency of surgery, repeat surgery, number of grafts bypassed, time on CPB, family history, tobacco use, cholesterol, hypertension, sedentary lifestyle, obesity, diabetes, pulmonary disease, renal disease, cardiac medications and postoperative complications of MI, arrhythmia and congestive heart failure. The dichotomised depression index was then added to the prediction models as a final step.

The results showed 28.1% of the study population was classified as presenting with clinically significant depressive symptoms. The mean PLOS was actually reported to be less for patients with clinically significant depressive symptoms than for patients without (10.91 s.d. 6.45 Vs 11.63 s.d. 9.91). No significant differences were found between patients who were depressed preoperatively and patients who were not depressed preoperatively in terms of the variables included in the models. At the first step of the multivariate analysis, significant effects were found for urgency of surgery and postoperative infection as predictors of PLOS, but adding the dichotomised depression index to the model at the second step did not have a significant effect.

The findings of this study are limited by the use of a small, exclusively male convenience sample drawn from a single hospital. The authors duly discussed the representativeness of the sample as a limitation to the external validity of the findings. The inclusion and exclusion criteria were explicit and the statistical methods were described with sufficient detail to enable replication. However, the power of the study was reduced by dichotomising the depression scores. This aspect has been criticised by Oxlad et al (2006) who commented that the study had insufficient power resulting from dichotomising a relatively small sample.

Whilst the significant findings for other outcomes and depression were discussed in detail and compared to previous studies, the non significant finding for depression and PLOS was not discussed.

In summary, the influence of preoperative depression as a predictor of PLOS in CABG patients has not been well studied and the findings that have been published are contradictory. Consequently, the effect of preoperative depressive symptoms on PLOS in patients who have undergone CABG is not well understood.

Within the studies reviewed, depression has been assessed using self-report measures of depressive symptoms in a defined period rather than a diagnostic tool. These are subject to a response bias but have commonly been used to measure depression and other psychological variables in the cardiac population.

The selection of assessment tools and the timing of the assessment of depressive symptoms varied between the studies reviewed which may explain the lack of consistency between the findings. The studies also lack the ability to determine if the depressive symptoms measured related to actual preoperative depression or were a manifestation of the impending surgery.

However measured, preoperative depression has only been entered as a variable in multivariate linear regression analyses of PLOS as a final step after the modelling of demographic, physiological and procedural variables. Consequently the predictive value of preoperative depression when entered simultaneously or before demographic, physiological and procedural variables is not known.

Due to the absence of conclusive evidence of an association between actual preoperative depression and PLOS, by either univariate or multivariate analysis, this variable has not therefore been identified as a potential predictor of PLOS in the current study.

4.2.3 OPTIMISM

Optimism is viewed as a stable dispositional characteristic that can predict health outcomes and an accumulating body of evidence supports the idea that having an optimistic outlook has a positive effect on individuals after CABG (Scheier et al, 1989; Fitzgerald et al, 1993; Scheier et al, 1999).

The concept of dispositional optimism refers to a generalised expectation that good things will happen, or beliefs that the probable outcome will be positive (Scheier and Carver, 1987). Scheier and Carver (1992) suggested that the mechanism by which optimism relates to health outcomes is through the differentiated use of coping strategies. Optimists are thought to use more active coping strategies, which are more effective in achieving positive outcomes.

Whilst research findings generally support the psychologically adaptive function of optimism and its importance as a coping resource during the

CABG experience (Scheier et al, 1989), pessimism has been associated with high levels of psychological distress and ineffective emotion focused coping strategies such as avoidance in CABG patients (Ben-Zur et al, 2000). However, it is suggested that optimism and pessimism are separate constructs that are not functional opposites and may be important at different times in the process of recovery from CABG (Mahler and Kulik, 2000).

There is little reported in the research literature of the separate predictive affects of either preoperative optimism or pessimism on PLOS with only two studies identified from the literature search. Both studies investigated optimism as the opposite of pessimism.

Contrada et al (2004) investigated optimism as a potential predictor of PLOS based on the findings of Scheier et al (1989) suggesting that this psychological variable may facilitate recovery from cardiac surgery. Dispositional optimism was assessed using the Life Orientation Test (Scheier et al, 1994) approximately a week before surgery. This tool is designed to measure individual differences in generalised optimism versus pessimism, and consists of four items reflecting optimism and four items reflecting pessimism.

The results showed that dispositional optimism was not associated with PLOS by either univariate analysis or multiple linear regression when entered with other psychosocial variables at the third step. This study has been reviewed in the previous section.

Later research has suggested that a pessimistic state of mind prior to elective CABG may be predictive of increased PLOS. Halpin and Barnett (2005) retrospectively studied 565 patients aged 65 years or over at a single American hospital to determine if a self-assessed pessimistic preoperative state of mind prior to elective CABG was predictive of postoperative complications and increased PLOS.

The patients were part of an ongoing cohort study to assess post CABG functional status changes from a baseline. Pessimism was selected for investigation as a potential predictor of PLOS and postoperative complications based on a lack of conclusive evidence that preoperative mental health state is predictive of adverse outcomes.

Patients were stratified into dichotomous categories of optimistic or pessimistic groups based on their preoperative mental health subscale scores on the Medical Outcomes Trust SF-20 Questionnaire, a standardised, validated questionnaire designed to measure patient functional health status (Stewart et al, 1998). The mental health subscale measures general mood or effect in the last month as continuous variables from zero (worst) to 100 (best). Those with a score of 70 or more were classified as optimistic, whilst those scoring less than 70 were classified as pessimistic, as determined by the internal institution's consensus and the benchmark for quality initiatives.

The results showed that a pessimistic state of mind increased PLOS by 1.65 days. Even after adjustment for age, gender and severity of disease, the average PLOS for pessimistic patients was 1.52 to 1.65 days longer than for optimistic patients. Pessimistic patients also had significantly higher rates of smoking and hypertension, and had a significantly greater risk of a postoperative permanent stroke and prolonged ventilation time compared to optimistic patients.

Again, the validity of the tool to measure the psychological variable selected is questionable and was probably selected due to the convenience and economic benefits of using previously collected data. Whilst lower scores on the SF-36 and SF-12 have both been associated with pessimism as measured using the Life Orientation Test (Scheier, 1994) and the Optimism-Pessimism scale of the Minnesota Multiphasic Personality Inventory (Colligan et al, 1994), (See for example Kung et al, 2006; Moyer et al, 2003), the validity of the SF-20 to measure pessimism or it's association with pessimism has not been established in the literature. Consequently, the significant results of an association between "pessimism" and PLOS that was reported in this study more accurately refers to an association between PLOS and a score less than 70 on the mental health subscale of the SF-20.

The rationale for the selection of the mental health subscale of the SF-20 to measure pessimism rather than a recognised and validated measure of this construct was not given. Similarly, the appropriateness of the SF-20 as a measure to categorise patients as pessimistic or optimistic was not discussed by the authors.

The authors did identify the choice of cut-off for the categorisation of pessimism, was somewhat arbitrary, and the self-assessment nature of the instrument as limitations of the study; but they did not discuss these issues any further. The authors also conceded that no attempt was made to control for preoperative clinical depression or address the issue of pre- or postoperative family support in the analysis; but did not identify or discuss any other possibly confounding variables.

As a result of the lack of research in this area, it is not clear whether it is more important to be preoperatively optimistic or simply not to be pessimistic in terms of PLOS following CABG. Consequently, neither optimism nor pessimism was identified as potential predictors of PLOS in the current study.

4.2.4 SOCIAL SUPPORT

Social support is increasingly recognised as an important aspect of life that relates to positive health and appears to be an important factor aiding recovery (Lindsay et al, 2001). Despite this, the influence of social support on PLOS after cardiac surgery has received little research attention.

King et al (1985) found from their study of coping strategies from the preoperative period to follow-up after cardiac surgery, that the social support sought by patients increased during this period. There is evidence that a network of support providers and the amount and perceived adequacy of social support is linked with many aspects of recovery from cardiac surgery (Yates, 1995; Oxman et al, 1997; Lindsay et al, 2001). The patient's spouse is frequently identified as the primary source of support. Kulik and Mahler (1989) reported that male CABG patients who had more visits from their spouse while hospitalised had a faster recovery and used less pain medication.

Three studies investigating social support as a predictor of PLOS after cardiac surgery were identified from the literature search (Contrada et al, 2004; Johnson et al, 2004; Anderson et al, 2006).

Contrada et al (2004) investigated perceived social support for an association with PLOS based on previous research linking social support with positive cardiovascular outcomes including recovery from cardiac surgery.

This study, previously reviewed, used the Multidimensional Scale of Perceived Social Support (Zimet at al, 1988), a validated 12-item self-report instrument designed to assess perceptions about support from family, friends and a significant other. The authors reported the degree to which patients' perceived social support was available from friends and family, when measured approximately one week before surgery, was not associated with PLOS by either univariate analysis or by stepped multivariate regression at the third step. The authors contrasted this finding with previous work and suggested that their failure to obtain an effect may have been attributable to factors related to measurement, such as the timing of assessment, or statistical power.

Similar findings were reported from a recent study by Anderson et al (2006) who examined the relationship between demographic, clinical and social characteristics of cardiac surgery patients with PLOS greater than seven days.

A convenience sample of 304 consecutive patients who underwent cardiac surgery over a two year period (2001 – 2003) at a single US veteran's hospital was used. Demographic details, preoperative risk factors and functional status, surgical and PLOS data were retrospectively retrieved from the Continuous Improvement in Cardiac Surgery Program database. This database had been used to develop models for mortality and morbidity risk associated with cardiac surgery. Two social variables were included in the analysis; whether a patient lived alone and caregiver availability. These were determined by review of the social history recorded in the patient's electronic medical record.

Following a detailed power calculation, univariate analyses and multivariate logistic regression models were used to evaluate risk factors for PLOS greater than seven days and to predict discharge to rehabilitation or home. By univariate analysis, the following variables were significantly associated with PLOS greater than seven days: age, haemoglobin value, complex surgery, number of coronary arteries bypassed, chronic obstructive pulmonary disease, dyspnoea classification, and functional status. These variables were subsequently entered into the logistic regression model.

The findings of this study did not support the addition of social variables in the prediction of PLOS greater than seven days. Living alone and caregiver availability did not influence PLOS by univariate analysis and therefore were not included in the multivariate analysis.

By multivariate analysis, age, complex surgery, and chronic obstructive pulmonary disease differed between patients with PLOS less than or equal to seven days and those who stayed longer. However, there was no test of the predictive power of this model or validation on another sample.

The study was motivated by the desire to plan inpatient cardiac rehabilitative services as an alternative to delayed discharge. The authors clearly stated the aims and purpose of the study, but the findings are limited by the use of a convenience sample from a single centre. The authors acknowledged the study was limited by the retrospective design and the fact that the findings for an all male, elderly white sample, were of limited application to the general population.

The secondary analysis of database information and data retrospectively retrieved from patient notes was limited to the variables and definitions for which the data was originally collected and assumed the records were accurate and complete. The authors acknowledged the analysis of social variables was limited to only two components and, although not discussed, the selection of these variables rather than specific measures of social support was probably due to the fact that this information had already been collected.

The exclusion criteria were explicit but the methods were not sufficiently described and comprehensive enough to enable replication. In particular, the description of which variables were included in the univariate analysis was not clear and definitions were only given for the two social variables.

Unfortunately the authors did not discuss the non significant finding in relation to the two social variables for the outcome of PLOS greater than seven days. They also did not contrast their finding with previous univariate research of social variables and PLOS which they included in the literature review.

In contrast to the findings of Contrada et al (2004) and Anderson et al (2006), Johnson et al (2004) reported that “social risk factors” including feeling lonely often, not having someone to trust and confide in, living alone, and not enough social contact were univariately and multivariately associated with prolonged stay. This study is reviewed in section 2.4.6.

Based on the findings of the studies reviewed, perceived social support was not identified as a potential predictor of PLOS in the current study. However, the influence of living alone was hypothesised to influence PLOS.

4.2.5 SOCIOECONOMIC DEPRIVATION

There is some evidence that socioeconomic deprivation is associated with longer PLOS after CABG. However, the only study identified from the literature search which investigated the influence of socioeconomic deprivation on PLOS did not do so as a primary outcome.

Based on the association with mortality and morbidity from CAD, Taylor et al (2003) investigated the effects of socioeconomic deprivation on the cardiovascular risk factors and postoperative clinical outcomes of 3578 patients undergoing CABG surgery at the Bristol Royal Infirmary. This retrospective analysis of prospectively collected data on the surgical population of the Southwest of England between April 1996 and August 2000 used the *Carstairs Index* (Carstairs and Morris, 1991) to measure the socioeconomic deprivation of the patients' area of residence.

This aggregate measure of socioeconomic deprivation was developed to help explain geographical variations in health data (Carstairs, 1995). It is based on 1991 Scottish census data of four indicators of material disadvantage in the population; car ownership, male unemployment, overcrowding, and social class within postcodes. This was divided into quintiles, where one denoted the least deprived and five the most deprived.

The results showed that hospital length of stay was significantly longer in the most deprived groups, whilst higher deprivation scores were also associated with younger age, greater BMI, diabetes, smoking at the time of surgery, and higher EuroSCORE's. Unfortunately, PLOS was not the primary outcome analysed in this study and was not discussed in any detail.

The usefulness of this study for the current investigation is limited by the use of secondary data retrieved from a convenience sample. Consequently, the data was not collected to address the research question and so may not have identified and measured an important variable. The findings may also not be generalised to the wider population. However, as exploratory data, the significant findings associating socioeconomic deprivation measured using the Carstairs index with PLOS after CABG surgery in the population studied, identifies this variable as worthy of further investigation in the current study population.

Whilst, the Carstairs index used in the study highlights the potential importance of socioeconomic circumstances on PLOS, it does not claim to reflect social deprivation. The index is designed to measure the material deprivation of geographical areas rather than individuals, and uses an aggregate approach to measure the deprivation of the area of residence. There are disadvantages to both these methods.

For example, there may be considerable heterogeneity within an area of residence that is concealed by the aggregate approach and it is also problematic to make inferences about individuals based on the analysis of groups (McLaren and Bains, 1998). Socioeconomic deprivation may also be based on individual data such as social class based on occupation, although this too is problematic particularly for women and individuals who have retired (Rose and O'Reilly, 1997).

As an aggregate measure, the overall index is dependent on the variables and sources of data used within each domain which may limit the robustness of the tool. The Carstairs index is based on assumptions about the variables that best represent material deprivation. However, car ownership, for example, may be an essential in rural areas and not representative of material resources (McLoone, 1995). In addition, as the index is developed from census data it can only be updated every ten years (McLaren and Bains, 1998).

Area-based scores such as the Carstairs Index are considered to provide a better indication of deprivation in urban than rural areas because populations with a mix of deprived and less deprived households are more likely to occur in rural areas and have middle ranking scores (McLoone, 1995; McLaren and Bains, 1998). Furthermore, the scores from postcode areas with populations less than 2000 are susceptible to random variation (McLoone, 1995).

Despite these limitations, area-based, aggregate approaches such as the Carstairs index, which are derived from large datasets of proxy information, currently offer the most convenient and reliable tools for measuring socioeconomic deprivation.

The results of the study suggest that material deprivation is both directly associated with PLOS and with variables that have been found to be predictive of PLOS, although the direction of influence was not established by the use of a cross-sectional sample. However, there is no generally agreed definition of deprivation which may also be conceptualised in terms of social deprivation or multiple forms of deprivation such as low income, poor housing, and unemployment as well as access to material resources (McLaren and Bains, 1998). These definitions of deprivation remain unexplored in relation to PLOS after cardiac surgery.

Consequently, deprivation was identified as a potential predictor of PLOS worthy of further investigation and hypothesised to influence this outcome.

4.2.6 PATIENT-REPORTED HEALTH STATUS

Whilst the influence of physical, psychological and social variables on patient outcomes following CABG have been studied independent of each other; research investigating the influence of patient-reported preoperative health status measures the combined influence of these variables for the individual patient. The research given its very nature relies upon a subjective measurement, as opposed to an objective one.

Measurements of health status, as perceived by the patient, can be used to evaluate the impact of a condition in terms of physical, psychological, social and role function and general health perception. There are a range of self-report health-status measurement tools developed to assess and quantify health-related quality of life but such tools vary in the constructs they measure.

The relationship between patient-reported health status and patient outcomes is well established within the literature (Rumsfield et al, 1999; Lindsay et al, 2001). However, only two studies investigating the influence of patient-reported health status on PLOS were identified from the literature search. The studies by Curtis et al (2002) and Johnson et al (2004) suggest that a patients' perceived general health status may influence outcomes following CABG.

For risk stratification purposes, Curtis et al (2002) investigated whether patient-reported preoperative health status, as measured by the Physical (PCS) and Mental Component (MCS) Summary scores of the SF-36, predicted in-hospital mortality and prolonged PLOS after CABG after controlling for established clinical predictors of these outcomes. Patient reported health status was investigated as a potential predictor based on previous research suggesting that this variable is predictive of mortality, independent of clinical information.

This two-year American prospective cohort study involved the secondary analysis of data collected from seven hospitals contributed for the purpose of benchmarking and quality improvement initiatives. A convenience sample of 1751 adults undergoing isolated CABG who completed the SF-36 as part of their admission assessment and were discharged alive was used. Prolonged PLOS was defined as more than 14 days as this corresponded to the 90th percentile of CABG length of stay for the Medicare population.

The clinical variables investigated were described as a positive stress test, BSA, creatinine, haematocrit, ejection fraction, congestive heart failure, chronic obstructive pulmonary disease, cardiogenic shock, mitral regurgitation, unstable angina, history of stroke or transischemic attack, diabetes, hypercholesterolaemia, hypertension, prior MI, prior CABG, PVD, renal disease, operative priority, the number of distal anastomoses, and complications and adverse events that occurred between surgery and discharge from hospital.

Univariate logistic regression was used to identify significant clinical predictors of prolonged stay which were then used to develop a clinical model. Each of the health status variables were then added to the final clinical models.

The results showed that cardiogenic shock, stroke/transischaemic attack, renal disease, hypertension, diabetes, congestive heart failure, chronic obstructive pulmonary disease, prior CABG, unstable angina, PVD, age, ejection fraction, creatinine, priority of surgery, previous MI, gender, haematocrit, MCS score and PCS score were significant univariate predictors of PLOS. Patients with a prolonged PLOS had significantly lower PCS, MCS and SF-36 subscale scores.

By multivariate analysis, the PCS was a significant predictor of prolonged PLOS beyond traditional clinical variables. A ten-point decrease in the PCS increased the odds of a prolonged PLOS by 33%, but a ten-point decrease in the MCS score was not associated with extended PLOS. Model discrimination assessed using the c-statistic or area under the ROC curve increased from 0.76 to 0.77 and 0.78 when summary scores and individual SF-36 scales were added to the clinical model respectively.

The authors concluded that the PCS score was independently and significantly associated with prolonged PLOS after controlling for clinical variables. However, the mechanism by which lower scores were associated with worse outcomes was unclear and further research was recommended to understand those relationships more clearly. The authors also added that other measures of patient-reported health status may be more specific but that the cost and inconvenience of data collection should be considered.

The findings of this study are strengthened by its prospective multi-centre design. The research question and the inclusion and exclusion criteria were explicit and the variables were reasonably well-reported. However, the statistical methods were not comprehensively described. The authors discussed the limitation of analysing incomplete secondary data which they conceded had resulted in a selection bias towards a younger and healthier sample of the population studied. These concerns limit the internal and external validity of the findings and the study, which again investigated only the added explanatory power that may be provided by self-reported health status to improve a predictive model developed from traditional demographic and physiological variables.

A similar study by Johnson et al (2004) hypothesised that poorer self-reported health and greater social risk were significantly associated with an extended PLOS, defined as more than seven days. Patient-reported health status was investigated as a potential predictor of PLOS based on the previous association with mortality after CABG.

This prospective cohort study involved the secondary analysis of pilot data collected for a quality improvement program involving 1073 patients from 14 American hospitals undergoing isolated CABG surgery over a 17-month period between 1995 and 1996. Out of those surveyed, 64% of the sample enrolled before surgery and the remaining 36% completed the baseline surveys reflecting their preoperative status two to seven days postoperatively.

The analysis included the variables in the following groups a) demographic variables: age, gender, income, marital status, education, and insurance status, b) hospital site, c) social risk variables: feels lonely often, not having someone to trust and confide in, lives alone, and not enough social contact d) health status defined by the Medical Outcomes Short-Form 36 (SF-36) and the Seattle Angina Questionnaire, and clinical variables: diabetes, creatinine, hypertension, PVD, cerebral vascular accident, chronic obstructive pulmonary disease, smoking history, previous MI, unstable angina, priority of surgery, previous cardiac surgery, ejection fraction, number of diseased vessels, cardiogenic shock, preoperative intra-aortic balloon pump, preoperative use of intravenous nitrates, inotropic agents, and presence of aortic or mitral valve disease.

The primary outcome of PLOS was dichotomised due to the skewed distribution of this variable. PLOS of seven or more days was selected to reflect a clinically meaningful cut-off point of patients with higher costs and incidence of postoperative complications. Variables significantly associated with PLOS greater than or equal to seven days by univariate analysis were entered into a multivariate forward logistic regression analysis.

Seventeen clinical variables were significantly associated with extended PLOS including: congestive heart failure, intra-aortic balloon pump, poor ejection fraction, co-morbidity score, cardiogenic shock, and preoperative length of stay more than two days. Not being married, unemployment, one or more social risk factors, and multiple SF-36 and Seattle Angina Questionnaire domains were also associated with this outcome.

By multivariate analysis, age, gender, co-morbidity score, prior CABG, intra-aortic balloon pump, congestive heart failure, emergency or salvage operation, and preoperative length of stay greater than two days were associated with extended PLOS. Consistent with previous studies, the hospital site was the most highly associated with extended PLOS after controlling for clinical variables (Ghali et al, 1999; Rosen et al, 1999; Butterworth et al, 2000). The SF-36 health perceptions value and the social risk factors variable were independently predictive of extended PLOS when entered after site and all other clinical variables were examined.

The authors concluded that patient self-reported measures of health status and socioeconomic variables added significantly to the precision of models predicting extended PLOS after CABG. However, they also concurred that pre-existing institutional practice patterns and efficiency may be the most important determinant of PLOS but that case mix also has an important role in predicting which patients are likely to stay longer than average.

The findings of this study are strengthened by its prospective multi-centre design. The research question and the inclusion and exclusion criteria were explicit and the variables were well-reported. However, the statistical methods were not comprehensively described and it is questionable whether the 36% of the surveys completed by patients during the postoperative period actually reflected the preoperative status of these patients.

Again, the authors discussed the limitation posed by the incomplete capture of consecutive patients by contributing hospitals which may have resulted in a selection bias with the study sample being a healthier subset of the Washington State CABG population. The findings are also limited by the secondary analysis of data as previously discussed. These concerns limit the internal and external validity of the findings of the study, which again investigated only the added explanatory power that may be provided by self-reported health status and social risk factors to improve a predictive model developed from traditional demographic and physiological variables.

Based on the studies reviewed, patient-reported health status may influence outcomes including PLOS after CABG. However, this has not been widely studied and further conclusive evidence is required in order to identify this variable as a potential predictor of PLOS.

Table 4.2.1 summarises the statistical association of each of the psychosocial variables identified in this section with some measure of PLOS after cardiac surgery.

TABLE 4.2.1:
SUMMARY OF THE ASSOCIATION BETWEEN POSPTOPERATIVE LENGTH OF STAY AND PSYCHOSOCIAL VARIABLES.

Variable	Significantly associated with PLOS	Not associated with PLOS
Anxiety		Stengrevics et al (1996) – State trait anxiety Oxlad et al (2006) - Depression Anxiety Stress Scales
Depression	Oxlad et al (2006) – Depression Anxiety Stress Scales Contrada et al – Beck Depression Inventory	Saur et al (2001) – SF-36 Burg et al (2003) - BDI
Optimism	Halpin and Barnet et al (2005) – SF-20 mental health domain	Contrada et al (2004) – Life Orientation Test
Social Support	Johnson et al (2004)	Contrada et al (2004) – Multidimensional Scale of Perceived Social Support) Anderson et al (2006) – Living alone, caregiver support
Hostility		Contrada et al (2004) – Aggression Questionnaire
Religiousness	Contrada et al (2004) – Religious attendance and beliefs	
Post Traumatic Stress Disorder	Oxlad et al (2006) – Post Traumatic Stress Scale	
Socioeconomic Deprivation	Taylor et al (2003) – Carstairs Index	
Patient-Reported Health Status	Curtis et al (2002) – SF-36 Johnson et al (2004) – SF-36 and Seattle Angina Questionnaire	

Table 4.2.2 summarises the research design and findings of studies that have included psychosocial variables in the multivariate analysis of some measure of PLOS.

TABLE 4.2.2:
SUMMARY OF MULTIVARIATE STUDIES THAT INCLUDE PSYCHOSOCIAL VARIABLES

Study	Design	Data Collection and statistical methods	Procedure(s) studied and outcome measured	Variables and stage of entry to model	Additional variability accounted for	Statistically significant variables
Stengrevics et al (1996)	Observational Convenience sample N = 104 Single US hospital	Prospective 24-48 hours preoperatively Review of records general linear modelling	Cardiac surgery PLOS	1st Medical and sociodemographic – six variables		NYHA and valve surgery
				2nd State and trait anxiety and anger		State anger
Contrada et al (2004) To examine religiousness as another psychosocial variable that may influence adaptation to heart surgery.	Observational Convenience sample 1996-1998 N = 142 Single US hospital	Prospectively, a week prior to surgery and review of medical records Stepped linear regression	CABG and/or heart valve surgery PLOS	1st Demographic – five variables	10.8%	Age and gender
				2nd Physiological – ten variables	8.5%	Anaesthetic time
				3rd Psychosocial: Depressive symptoms, dispositional optimism, perceived social support and trait hostility.	5.8%	Depressive symptoms
				4th Religiousness: religious denomination, attendance, prayers and beliefs	6.1%	Attendance and beliefs

Study	**Design**	**Data Collection and statistical methods**	**Procedure(s) studied and outcome measured**	**Variables and stage of entry to model**		**Additional variability accounted for**		**Statistically significant variables**	
Oxlad et al (2006) To investigate preoperative psychological functioning variables would as risk factors for longer PLOS following CABG surgery.	Observational Convenience sample 2002-2003 N = 119 Two South Australian Hospitals	Prospective Telephone interview prior to surgery and review of medical records Stepped linear regression	Elective isolated CABG or combined CABG/valve surgery PLOS	**MODEL1**	**MODEL 2**	**MODEL1**	**MODEL2**	**MODEL1**	**MODEL2**
				1st Demographic – six variables Physiological – 11 variables Psychiatric history – three variables Preoperative variables – three variables	1st Demographic – six variables Physiological – 11 variables Psychiatric history – three variables Preoperative variables – three variables	8%	8%	Ethnicity and tobacco use	Ethnicity and tobacco use
				2nd Psychological variables – depression, anxiety, PTSD symptoms	2nd Operative and postoperative – five variables	5%	24.5%	Depression and PTSD symptoms	CPB time, mechanical ventilation time and number of complications
					3rd Psychological variables – depression, anxiety, PTSD symptoms		4.4%		Depression and PTSD symptoms

Study	Design	Data Collection and statistical methods	Procedure(s) studied and outcome measured	Variables and stage of entry to model	Additional variability accounted for	Statistically significant variables
Burg et al (2003) To determine the independent contribution of preoperative depression to short-term outcomes	Observational Convenience sample 1996-1997 N = 89 male veterans Single US Hospital	Prospective Questionnaire a week prior to surgery and review of medical records Stepwise Stepped linear regression	Elective isolated CABG PLOS	1st Medical, surgical and psychosocial – 22 variables	Not stated	Urgency of surgery and postoperative infection.
				2nd Dichotomised depression index	Not stated	None
Curtis et al (2002) Investigated whether patient-reported health status predicted prolonged PLOS	Observational Convenience sample 1993-1995 N = 1751 Seven US Hospitals	Retrospective Secondary analysis of benchmarking data Logistic regression	Isolated CABG PLOS within 14 days	19 demographic, physiological and psychosocial variables with and without patient reported health status (PCS and MCS summary scores).	Not stated	PCS was a significant predictor of prolonged PLOS beyond traditional clinical variables

Study	Design	Data Collection and statistical methods	Procedure(s) studied and outcome measured	Variables and stage of entry to model	Additional variability accounted for	Statistically significant variables
Johnson et al (2004) Hypothesised that poorer self-reported health and greater social risk were significantly associated with extended PLOS	Observational Convenience sample 1995-1996 N = 1073 14 US Hospitals	Prospective Questionnaire and Secondary analysis of audit data Logistic forward stepwise regression	Isolated CABG PLOS seven days or more days	Demographic and preoperative clinical variables Social risk factors and health status	c-statistic value 0.826	Site, age, gender, co-morbidity score, Prior CABG, preoperative balloon pump, congestive heart failure, emergent or salvage procedure, preoperative stay, SF-36 health perceptions value, and social risk factors

4.2.7 SUMMARY

Whilst it is evident that the relationship between psychosocial variables and outcomes following cardiac surgery has been the subject of increasing research interest, much of the literature has focused on long-term outcomes such as mortality, morbidity and readmission rates. Relatively few studies have investigated the impact of psychosocial variables on the immediate postoperative period and PLOS.

Several variables have been identified as potential predictors of PLOS in the psychosocial literature including: fear and anxiety, depression, optimism, social support, socioeconomic deprivation, and patient-reported health status. The possible mechanisms by which these variables may influence PLOS have been discussed with reference to the stress, appraisal and coping theoretical framework of the study and supporting literature.

Again, all the studies reviewed in this section are observational and use convenience samples of consecutive patients undergoing surgery rather than probability sampling. This indicates that these are the most appropriate and feasible methods of investigating the research question. Prospective data collection methods have been used for psychosocial variables where these have not already been routinely measured and recorded. These have then been combined with retrospective methods for the collection of routinely recorded demographic, physiological and procedural data collection. The latter method is usually more convenient and economical and increases the utility of previously collected data.

Multi-centre studies with larger sample sizes tend to perform secondary analyses of audit data from large databases (Curtis et al, 2002; Johnson et al, 2004). Data collected in this way is limited to the variables and definitions for which the data was originally collected and assumes the records are accurate and complete. The instruments used to measure the psychological variable of interest in the original analysis may also not be the most appropriate, or even a valid measure of the variable of interest in the secondary analysis.

The psychosocial studies reviewed are subject to conceptual as well as methodological limitations to the internal and external validity of their findings. Theoretical and operational definitions of the concept being investigated vary between theorists and researchers whilst varying measurement tools are utilised in the studies; making comparisons problematic. Furthermore, the studies tend to rely on cross-sectional, rather than longitudinal research designs thereby reducing the concept investigated to a static event rather than a dynamic evolving construct usually defined in terms of a process thus limiting the findings to descriptive rather than causal relationships.

Unfortunately, as the majority of multivariate analyses reviewed in this section tend to analyse only the added explanatory power of psychosocial variables when entered into the modelling process after demographic, physiological and procedural variables have been accounted for; the relative predictive value of these variables is unknown. This probably reflects economic concerns of the cost and convenience of collecting data on psychosocial variables if the degree of variance explained by these variables is relatively limited, when compared to the variance which can already be explained by routinely collected demographic, physiological and procedural variables. Consequently, only the extent of the additional variance that can be accounted for by psychosocial variables is usually of interest to researchers, clinicians and other healthcare professionals.

The alternative use of stepwise methods to limit the number of variables in a model has limited power to detect important variables due to the influence of random variation in the data. Both methods limit the usefulness of the findings to identify which psychosocial variables are predictive of PLOS after CABG by multivariate analysis. However, the comparatively small amount of psychosocial literature in this field suggests the possibility that psychosocial data may add significant and clinically meaningful information to models predicting PLOS after CABG.

Given the conceptual and methodological limitations identified, there is some conflicting evidence that the following psychosocial variables may account for some additional variance in PLOS by staged entry multivariate analysis; depression (Contrada et al, 2004; Oxlad et al, 2006), religiousness (Contrada et al, 2004), post-traumatic stress (Oxlad et al, 2006), and patient-reported health status (Curtis et al, 2002; Johnson et al, 2004).

There is no evidence that anxiety or social support can assist in the prediction of PLOS (Stengrevics et al, 1996; Contrada et al, 2004; Anderson et al, 2006; Oxlad et al, 2006), although social risk factors such as living alone may exert an influence (Johnson et al (2004). Pessimism (Halpin and Barnet, 2005) and socioeconomic deprivation (Taylor et al, 2003) have been associated with some measure of PLOS by univariate analysis.

Following this review of the psychosocial literature, the following variables were identified as theoretical predictors of PLOS and investigated in the current study: time on the waiting list, living alone, marital status, employment status, and socioeconomic deprivation. These variables were considered antecedents to impending CABG which are important to the appraisal of this stressful event and the subsequent selection of coping strategies, and therefore hypothesised to influence PLOS.

4.3 CONCLUSIONS OF THE LITERATURE REVIEW

The development and validation of models to predict PLOS after CABG surgery is of interest for a variety of reasons. These include the ability to predict resource utilisation, the facilitation of effective patient management, and the comparison of risk-adjusted PLOS for benchmarking purposes.

A search and review of the literature has shown that the multivariate prediction of PLOS after cardiac surgery in adults has received a considerable amount of investigation. The literature is dominated by studies conducted in American populations whilst it remains a relatively unexplored area of investigation in the UK population.

The approach and statistical methods used by researchers vary according to the motivation for and aim of the study. The focus of research questions include predictions of short PLOS, prolonged PLOS, predicting PLOS as a continuous variable, predicting the postoperative complications that delay discharge, and a combination of these predictions.

Despite differences between studies in terms of the populations included, the methods used, data collection, and the years in which the data were collected, a number of demographic, physiological and procedural predictor variables have consistently been associated with PLOS by multivariate analysis. However, where the studies have included an evaluation of their resultant models, their findings also suggest that data on demographic, physiological and procedural variables can explain only a small amount of the variability observed in PLOS. Meanwhile, hospital comparison data suggests that the provider effect can explain a considerable amount of the variability in this outcome raising the possibility of quality and efficiency issues. However, the specific hospital characteristics influencing PLOS have not been identified in any of the studies.

Despite extensive research attention, gaps remain in the current body of knowledge as the vast majority of multivariate analyses have been performed entirely upon demographic, physiological and procedural predictor variables and have not investigated other potentially influential variables. This is likely to be because data on demographic, physiological and procedural variables are routinely collected for mortality and morbidity risk stratification purposes in both the UK and the US. Consequently, little is known of the influence of psychosocial variables on PLOS by multivariate analysis.

The studies reviewed are generally limited by the reliance on convenience samples and the use of data that are routinely collected for mortality and morbidity risk stratification. A common theme among the multivariate studies reviewed is the lack of a clear rationale for the selection of variables studied which, in most cases, appear to be variables for which information is routinely collected and were therefore readily available.

Whilst the use of demographic, physiological and procedural data may offer high reliability and validity, and economic benefits if it has already been collected, the research suggests these are poor predictors of PLOS, typically accounting for less than 20% of the variation. Consequently, the resulting models do not adequately explain the complexity of the relationship between PLOS and the CABG population.

It is evident from the psychosocial cardiac literature that knowledge of the patient's preoperative psychosocial status is an important aspect to be considered in their postoperative recovery and may be important in the prediction of PLOS. However, despite increasing research interest in the influence of psychosocial variables on outcomes after cardiac surgery, these have rarely been included in multivariate models designed to predict PLOS.

The omission of psychosocial variables from many multivariate analyses limits what is known about the relative influence of the demographic, physiological and procedural variables when psychosocial variables are also taken into account. It also limits the understanding of the complex phenomena of predicting PLOS after CABG surgery. Incomplete knowledge of the relationship between PLOS and preoperative patient variables may consequently lead to ineffective patient management.

A limited number of studies have recognised the additional potential for psychosocial variables to assist in the prediction of patient PLOS after CABG after traditional clinical variables have been accounted for, typically 5-6%. These studies support the hypothesis that extending the assessment process to include preoperative psychosocial as well as traditional data may improve the ability to predict PLOS, but perhaps only to a limited degree.

Whether the inclusion of psychosocial variables can improve the amount of variability in PLOS explained by multivariate modelling is an under researched area of investigation. The relatively small amount of psychosocial literature in this field and the investigation of only the additional explanatory value of psychosocial variables limit the usefulness of the multivariate psychosocial literature to identify which psychosocial variables are predictive of PLOS when considered simultaneously with demographic, physiological and procedural variables. The psychosocial variables identified as potential predictors of PLOS as a result of the literature review will therefore be simultaneously investigated in Phase I of the current study.

Previous attempts to model PLOS have also lacked a theoretical framework. In the current study, the stress and coping conceptualisation has been used to explore the ways in which the psychosocial variables identified; are antecedent to the appraisal of stress associated with impending CABG surgery and the subsequent selection of coping strategies. Perceived stress and health locus of control are central to the theory and were additionally investigated in Phase II of the current study.

Perceived stress and health locus of control were not investigated in phase I of the study, for reasons of cost and inconvenience to both patients and staff. The collection of the data would have been both time consuming and also potentially intrusive, at a time which has already identified as being stressful for the patients in previous chapters. As a result of the lack of data available to justify their inclusion in Phase I coupled with the difficulties in collecting the data for a large patient sample, it was decided to investigate these variables for patients in the smaller Phase II sample.

As a result of the literature review and the application of the theoretical framework, all the variables identified for investigation had a sound empirical or theoretical rationale for their selection. The methods employed in the investigation are described in the next chapter.

CHAPTER 5

METHODS

This chapter describes the research methods used in the study. The rationale for the chosen methods and the selection of variables reflects both a theory-driven and empirically based approach.

The methods employed to investigate the research question and test the hypotheses generated from the literature review were informed and guided by the studies discussed in the literature review. Inevitably, given the nature of the investigation, there are some limitations associated with the methods used in the study. These are discussed in chapter 7.

The research question was: "Can postoperative length of stay or discharge within five days of first time isolated CABG be predicted from preoperative patient variables?"

The aims of the study were:

1. To determine the characteristics of the local CABG population.
2. Develop and validate models to predict PLOS and discharge within five days of CABG.
3. Analyse the relationships between appraised stress and feelings of control, and PLOS and discharge within five days of CABG.
4. Analyse differences between stress appraisals and feelings of control, and the characteristics of the local CABG population.
5. Evaluate the potential contribution of stress appraisals and feelings of control, to the prediction of PLOS and discharge within five days of CABG.

Based on the literature cited and the theoretical considerations of Lazarus and Folkman (1984) it was hypothesised that:

1. A difference will be observed between PLOS after first time isolated CABG and each of the individual preoperative variables studied.
2. A difference will be observed between discharge within five days of first time CABG and each of the individual preoperative variables studied.
3. PLOS can be predicted from one or more of the preoperative variables studied in Phase I.
4. Discharge within five days can be predicted from one or more of the preoperative variables studied in Phase I.

5.1 DESIGN

An observational research design was used to address the research question. The term 'observational' applies to research in which no intervention is made and the researcher observes the variables of interest in their natural setting (Mann, 2003). Observational methods can provide high external validity as they enable large numbers of patients to be studied and maintain the integrity of the context in which care is provided (Black, 1996).

The study was conducted in two Phases. In Phase I models to predict PLOS as a continuous variable and as a categorical dichotomy with an underlying continuum of PLOS of less than or equal to five days or greater than five days were constructed. In Phase II, the models derived for the prediction of PLOS and PLOS within five days were prospectively validated on another cohort of patients.

The influence of the preoperative patient's perceived stress and health locus of control on PLOS were also investigated in Phase II. As previously discussed the decision to investigate these variables only in Phase II was made due to absence of any prior empirical investigation of an association between these variables and PLOS. For reasons of potential inconvenience for the patient and cost implications, an evaluation of their potential influence on PLOS in a smaller sample of patients was first required. However it would not have been feasible to collect and analyse this data in a subset of the sample of patients in Phase I and then continue to collect this data based on the evaluation. Therefore the decision was made to evaluate the potential of these variables as predictors of PLOS in the smaller Phase II sample which would also provide more contemporary data.

Phase I

A cross-sectional survey design was selected to retrospectively examine associations between the all the variables and PLOS and to develop predictive models. In a cross-sectional study each patient is examined at one point in time. Such studies are useful to identify associations that can then be more rigorously studied using a cohort study (Mann, 2003).

The advantages of cross-sectional research include the use of only one sample, data are collected only once, and many variables can be examined. An advantage of the retrospective design is the lack of one form of bias; because the outcome of current interest was not the original reason for the data to be collected this did not influence the data.

Phase II

A cohort design was used to prospectively test the effectiveness of the variables identified in Phase I to predict actual PLOS and PLOS within five days of CABG.

A Cohort study describes the study of the same group of patients over a period of time. The patients are selected before the outcome of interest is observed which allows the calculation of the effect of each variable on the probability of developing the outcome of interest (Mann, 2003).

PLOS for each patient was calculated for given values of the significant variables using the equations derived from the models developed in Phase I. The predictions were than compared with the patient’s actual PLOS.

Similarly, the likelihood of PLOS within five days was calculated for given values of the significant variables using the equations derived from the models developed in Phase I for this outcome. Patients were classified as predicted PLOS within five days if the value of the predicted probability was greater than 0.5, or predicted PLOS greater than five days if the predicted probability was less than or equal to 0.5.

The predictions were then compared to whether the patient was actually discharged within five days to assess the sensitivity and specificity of the model. Sensitivity is the ratio of true positives to all positives, referring to the proportion of positive cases that were correctly identified as positive. Sensitivity therefore measured how well the model performed in identifying patients with a PLOS of five days or less. Specificity is the ratio of true negatives to all negatives, referring to the proportion of negative cases that were correctly identified as negative. Specificity therefore measured how well the model performed in identifying patients with a PLOS more than five days.

The influence of perceived stress and health locus of control on the predictive ability of the models was then investigated for the cohort.

5.2 SAMPLE

5.2.1 Phase I

Inclusion criteria

A convenience sample of the total population was selected in order to obtain data for a large number of patients within a specified timeframe. The sample included all adult patients undergoing first time isolated CABG between 1st January 2005 and 31st December 2005 at two hospital sites which form a regional centre for cardiac surgery at a single NHS teaching trust in London. Isolated CABG refers to CABG without concomitant cardiac or vascular procedures at the time of bypass grafting.

Exclusion criteria

Patients undergoing repeat surgery or other types of cardiac surgery such as cardiac valve replacement/repair, great vessel repair, or combined procedures were excluded as these more complex procedures are associated with longer PLOS (Lazar et al, 1995; Tu et al, 1995; Keogh and Kinsman, 2002; Peterson et al, 2002; Anderson et al, 2006).

Patients who died in the base hospital on the same admission as surgery were excluded from the analysis since variables associated with high early operative mortality may artificially shorten PLOS if death is not accounted for or excluded (Rosen et al, 1999). The characteristics of patients who died were however compared with those included in the analysis.

Sample size

The general rule of at least 40 cases per variable to obtain a reliable for multiple regression model using stepwise methods was adhered to in order to calculate a sample size large enough to detect medium size effects with a conventional level of power of 0.80 and a two-tailed alpha equal to 0.05 (Tabachnick and Fidell, 2001: 117).

A total of 30 variables were identified from the literature review for univariate investigation in Phase I and if all these variables were found to be univariately associated with PLOS and subsequently entered into the multivariate analysis then a sample size of 1200 patients would be necessary using this method.

For logistic regression Peduzzi et al (1996) recommend that the smaller of the categories of the dependent variable have at least ten events per variable in the model. Applying this rule of thumb, if all 30 independent variables were entered into the logistic regression model then 300 patients discharged within five days of surgery and 300 patients discharged after five days of surgery would be required. In addition, for each categorical independent variable the number of cases of the smallest category should be considered in this way also.

The trust audit data revealed that 999 patients underwent first time isolated CABG during the financial year 2003-2004 and it was therefore expected that a similar number of patients would undergo the procedure during the year 2005. With an associated mortality rate of 1.9%, it was anticipated that 980 patients would be identified for Phase I of the study. Based on a priori knowledge of the proportion of patients discharged within five days in the study population, 316 patients (approximately a third) would be identified as PLOS within five days and 634 (approximately two thirds) as greater than five days.

If all 30 independent variables were entered into the logistic regression analysis then there would be 10.5 cases per variable for the smaller PLOS of five days or less category using the method recommended by Peduzzi et al (1996).

5.2.2 Phase II

Inclusion criteria

The sensitivity and specificity of the models developed in Phase I to predict PLOS and which patients would have a PLOS of five days or less were prospectively tested on another cohort of patients undergoing first time isolated CABG between 1st August 2007 and 31st January 2008. The inclusion criteria described for Phase I was also adopted for Phase II. The inclusion criteria for both Phases of the study are summarised in table 5.2.2.1

Only patients in the cohort who gave their informed consent and were able to understand the instructions and independently complete the Perceived Stress Scale (PSS) (Cohen et al, 1983) and the Multidimensional Health Locus of Control (MHLOC) Scale (Wallston et al, 1978) were included in the investigation of the influence of perceived stress and health locus of control on PLOS.

Exclusion criteria

The exclusion criteria described for Phase I was also applied to Phase II. In addition, patients who were unable to understand and complete the questionnaires independently or did not consent to participate in this part of the study were excluded from the investigation of perceived stress and health locus of control on PLOS.

TABLE 5.2.2.1
INCLUSION CRITERIA

<table>
<tr><th colspan="2">Inclusion Criteria</th></tr>
<tr><th>Phase I</th><th>Phase II</th></tr>
<tr><td rowspan="2">• All 1st time isolated CABG
• 1st January 2005 – 31st December 2005
• Two sites of a single NHS Trust</td><td>• All 1st time isolated CABG
• 1st August 2007 - 31st January 2008
• Two sites of a single NHS Trust</td></tr>
<tr><td>• Informed consent for PSS and MHLOC
• Able to complete PSS and MHLOC independently</td></tr>
</table>

Sample size

From 2003-2004 audit data, it was anticipated that 490 patients would be identified over six months, of which 147 patients (approximately 30%) would be identified as PLOS within five days and 343 (70%) as greater than five days.

5.3 DATA COLLECTION

5.3.1 Phase I

Variables in the Study

A large number of variables were included in order to minimise the possibility that any important ones were omitted. The decision of which variables to investigate was based on a priori knowledge, theoretical support of an association between various preoperative variables and PLOS after CABG, as identified from the literature review in Chapters 3 and 4.

The following variables were included based on empirical support of an association with some measure of PLOS by multivariate analysis as reviewed in section 4.1; age, gender, BSA, BMI, diabetes, hypertension, renal function, ejection fraction, MI, dyspnoea classification, angina classification, LMS disease, PVD, pulmonary disease, smoking history, the number of vessels bypassed, urgency of surgery, hospital of surgery, consultant surgeon, preoperative length of stay and ethnicity.

The following variables were included based on their theoretical influence on PLOS by multivariate analysis as identified by previous univariate analysis in chapters 3 and 4; Parsonnet score, EuroSCORE and use of CPB.

The following psychosocial variables were included based on their theoretical influence on PLOS by multivariate analysis as identified from literature reviewed in section 4.2; living alone, marital status, employment status, time on the waiting list and socioeconomic deprivation.

In addition, the day of the week on which the fifth day occurred was analysed to investigate the influence of planning for discharge on different days of the week.

Tables 5.3.1.1 and 5.3.1.2 summarise the empirical and theoretical support for each of the variables selected and a multivariate association with PLOS or PLOS ≤ 5 days.

TABLE 5.3.1.1:
SUMMARY OF VARIABLES WITH EMPIRICAL SUPPORT WITH POSTOPERATIVE LENGTH OF STAY BY MULTIVARIATE ANALYSIS

Group	Variable	Reference
Demographic	Age	Weintraub et al (1989) Lahey et al (1992) Tu et al (1995) Rosen et al(1999) Peterson et al (2002) Anderson et al (2006)
	Gender	Weintraub et al (1989) Tu et al (1995) Rosen et al (1999) Peterson et al (2002)
	Body surface area	Peterson et al (2002)
	Body mass index	Lahey et al (1992)
	Ethnicity	Peterson et al (2002)
Co-morbidities	Diabetes	Lazar et al (1995) Rosen et al (1999) Peterson et al (2002)
	Hypertension	Peterson et al (2002)
	Renal function	Lahey et al (1992) Lazar et al (1995) Rosen et al (1999) Peterson et al (2002)
	Ejection fraction	Weintraub et al (1989) Tu et al (1995) Peterson et al (2002)
	Myocardial infarction	Rosen et al (1999) Peterson et al (2002)
	Dyspnoea classification	Peterson et al (2002)
	Angina classification	Weintraub et al (1989)
	Peripheral vascular disease	Rosen et al (1999) Peterson et al (2002)
	Pulmonary disease	Rosen et al (1999) Peterson et al (2002) Anderson et al (2006)
	Smoking history	Peterson et al (2002)
Severity of illness	Left main stem disease	Peterson et al (2002)
	Number of vessels bypassed	Peterson et al (2002)
	Urgency of surgery	Weintraub et al (1989) Tu et al (1995) Peterson et al (2002)
	Preoperative length of stay	Lazar et al (1995)
operative/ organisational	Hospital of surgery	Peterson et al (2002)
	Consultant surgeon	Peterson et al (2002)

TABLE 5.3.1.2:
SUMMARY OF VARIABLES WITH THEORETICAL SUPPORT FOR A MULTIVARIATE ASSOCIATION WITH POSTOPERATIVE LENGTH OF STAY BY MULTIVARIATE ANALYSIS

Group	Variable	Reference
Demographic	Living alone	Johnson (2004) Anderson (2006)
	Marital status	King et al (1985)
	Employment status	Koivula et al (2001)
	Socioeconomic deprivation	Taylor et al (2003)
Severity of illness	Parsonnet score	Miller et al (1998)
	EuroSCORE	Toumpoulis et al (2005)
	Time on the waiting list	Bressler et al (1993) Underwood et al (1993) Bengston et al (1996) Cox et al (1996) Mark et al (1997) Jonsdottir and Baldursdottir (1998) Koivula et al (2001)
Operative/ organisational	Cardiopulmonary bypass	Jones and Weintraub (1996) Ascione et al (2000; 2001) Cleveland et al (2001) Plomomdon et al (2001) Puskas et al (2001) Van Dijk et al (2001) Angelini et al (2002) Magee et al (2002) Järvinen et al (2003) Puskas et al (2003) Racz et al (2004).

5.3.2 Secondary Data Sources

The data was obtained retrospectively from two sources. Data on the variables included in the study were routinely collected for either annual contribution to the SCTS Surgical Register and the National Adult Cardiac Surgical (NACS) Database or stored in the Trusts' computerised patient records.

The secondary use of previously collected data is an increasingly popular method of obtaining data that has been facilitated by advances in technology and the growth of large databases as a result of the demand for audit activity in healthcare (Closs and Cheater, 1996; Lee et al, 2005). Audit activities are now an integral component of the NHS that can provide high quality data for non experimental research (Black, 1992). The SCTS currently expects all hospitals within the UK to contribute to the collection of comprehensive and standardised data to enable a greater understanding of changing trends within the cardiac speciality and comparison of clinical performance with national and international standards.

Such databases can provide a convenient, efficient and inexpensive source of high quality, reliable, and standardised data for a large number of patients (Mann, 2003). However, the use of the database assumes that the records are accurate, reliable and complete.

Potential problems associated with the use of such secondary data are misclassification errors, subjective interpretations, and variation in coding practice as well as incomplete coding. In addition, the possibility of bias in the selection of patients, failure to achieve a homogenous distribution of variables between groups, lack of control for confounding variables, and failure to collect data on an important variable, all also limit the internal validity and reliability of analysing secondary data (Ferraris and Ferraris, 2003; Boslaugh, 2007).

Whilst the limitations of analysing secondary data have been acknowledged, the justification for this approach was the opportunity to maximise the utility of existing high quality data of acceptable validity and reliability that had already been collected for a large sample of patients. This would otherwise have been beyond the resources of a single researcher.

The data was collected independently of any hypotheses and by people other than the researcher thus diminishing the opportunity for observer bias. Trust audit personnel created a report for the study from which the researcher retrieved the data for the cross-section of the population identified and merged it with additional data from the Patient Administration System (PAS) and the Electronic Patient Record (EPR). The researcher then removed all identifying information and coded the variables. Table

5.3.2.1 illustrates the source of each data item.

TABLE 5.3.2.1:
SOURCE OF DATA

SCTS Surgical Register and the National Adult Cardiac Surgical Database	Patient Administration System and the Electronic Patient Record.
• Date of operation • Age • Gender • Body surface area • Body mass index • Postcode • Ethnic origin • Diabetes • Hypertension • Renal function • Ejection fraction • No. previous myocardial infarctions • Dyspnoea classification • Angina classification • Peripheral vascular disease • Pulmonary disease • Smoking history • Left main stem disease • No. vessels bypassed • Urgency of surgery • Parsonnet score (from hard data and including catastrophic states and other rare conditions) • EuroSCORE • Consultant surgeon • Hospital site • Use of cardiopulmonary bypass	• Marital status • Living alone • Employment status • Date on the waiting list • Date of admission • Date of discharge

5.3.2.1 Society of Cardiothoracic Surgeons Surgical Register and the National Adult Cardiac Surgical Database

Validation

All centres contributing to the SCTS Surgical Register and the NACS Database are required to collect, clean, collate, document and carefully check their data before submission to both the register and the database. Electronic data must be carefully scrutinised and validated locally against other record systems before being released. A non-medical administrator was responsible for management of the data collection process, maintenance of the quality of the data, and for validating the data.

Reliability

To ensure reliability, data was collected for every patient in an agreed minimum dataset using the Patient Analysis & Tracking System. The current minimum dataset was agreed by representatives of the SCTS, the NHS Information Authority, and the Central Cardiac Audit Database. The SCTS agreed minimum dataset for adult cardiac surgery uses standardised definitions which can be accessed online at http://www.ic.nhs.uk/our-services/improving-patient-care/the-national-clinical-audit-support-programme-ncasp/heart-disease/adult-cardiac-surgery/user-information.

The Parsonnet score (Parsonnet et al, 1989) and EuroSCORE (Roques et al, 1999) were calculated using a fixed algorithm so that all patients were scored in an unbiased and uniform manner (Appendix 1 and 2). In addition to the Parsonnet score from hard data, a second Parsonnet score including catastrophic states and rare conditions was calculated using all 16 variables as originally described by Parsonnet et al (1989). The inclusion of the subjective items of catastrophic states and rare conditions in the second score was dependent upon and reflective of the professional judgement of the Doctor responsible for calculating the score.

The Parsonnet score and EuroSCORE have been well established as valid and reliable measures of preoperative 30-day mortality risk. As discussed in chapter 3, the accuracy of the older Parsonnet score has decreased as practice has progressed but this variable was included in the investigation for several reasons; the Parsonnet score remains in use at the study centre where it is routinely calculated, it is calculated from different risk factors to the EuroSCORE which may be more pertinent to the prediction of PLOS irrespective of the weighting for mortality, and both mortality scoring systems have been independently associated with PLOS.

Parsonnet scores were used to categorise patients into one of the five Parsonnet score groups with associated mortality risks. Similarly, EuroSCORE's were used to categorise patients into one of three risk groups.

Dyspnoea was graded according to the New York Heart Association (NYHA) classification of heart failure (Criteria Committee of the New York Heart Association, 1964). Angina was classified using the Canadian Cardiovascular Society (CCS) grading system of angina pectoris (Campeau, 1976).

The associated definitions are compatible with all existing initiatives in the UK including the UK Heart Valve Registry and the British Cardiovascular Intervention Society. It is also comparable to the Society of Thoracic Surgeons (USA) dataset, and the European and US cardiac surgical databases. In addition, the SCTS agreed dataset was published in Chapter Five of the NSF for Coronary Heart Disease (Department of Health, 2000b) to provide a template for the mandatory audit requirements of NHS trusts (Keogh and Kinsman, 2002).

5.3.2.2 Patient Administration System and the Electronic Patient Record

Index of deprivation

The patient's postcode was used to derive an index of deprivation based on the Index of Multiple Deprivation 2004 survey (ID2004). The index is a theoretically weighted aggregate measure of seven types of deprivation: income, employment, health and disability, education, skills and training, housing and services, living environment, and crime (Office of the Deputy Prime Minister, 2004). The index is a snapshot measure of the spatial distribution of deprivation and is up-dated periodically.

A limitation of the aggregate approach used in the overall index of deprivation is that an area measured as relatively deprived by the index may contain large numbers of people who are not deprived and vice versa (Office of the Deputy Prime Minister, 2004).

The index is also dependent on the sources of data used within each domain that may limit the robustness of ID2004 as an index of deprivation. For example, evidence of low income is based on the count of the individuals receiving means-tested income support compared to the overall population of the area but non-take-up of these benefits may mean that this measure underestimates the extent of low income. Similarly, data on access to health services is used as indicators in the health deprivation and disability domain but such measures of perceived or expressed health need do not account for unidentified poor health.

Ethnic group

The patient's stated ethnic origin was classified using guidelines for the collection and classification of ethnic group data for England and/or Wales based on the 2001 census presentation (National Statistics, 2003). Ethnicity is a subjective and evolving concept and classifications require periodic up-dating.

Date calculations

PLOS was measured in days from the date of surgery until discharge from hospital and calculated from midnight and according to the number of nights in the hospital after surgery, taking only discrete positive integer values. The day of surgery was not included. This method is consistent with previous studies and within the cardiothoracic speciality.

Similarly, preoperative length of stay was measured in days from the date of admission until the date of surgery and time on the waiting list was measured in months from the date of placement on the waiting list to the date of surgery.

The variables included in the study, along with their definitions, level of measurement(s) and coding are summarised table 5.3.2.2.1.

TABLE 5.3.2.2.1:
VARIABLES INCLUDED IN THE STUDY: DEFINITIONS, LEVEL OF MEASUREMENT AND CODING

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Postoperative length of stay.	(1) ≤ 5 days (0) > 5 days		Days
Age		(1) < 51 years (2) 51-60 years (3) 61-70 years (4) > 70 years	Age in years
Gender	(1) Male (2) Female		
Body Surface Area (BSA)		(1) <1.70m^2 (2) 1.70-1.89m^2 (3) 1.90-2.39m^2 (4) >2.39m^2	BSA
Body Mass Index (BMI) (weight in kilograms / height in metres squared)		(1) < 20.0kg/m^2 (Underweight) (2) 20.0-24.9kg/m^2 (Normal weight) (3) 25.0-30.0kg/m^2 (Overweight) (4) 30.1-40.0kg/m^2 (Obese) (5) > 40.0kg/m^2 (Severely obese)	BMI
Marital status	(1) Married (2) Co-habiting (3) Separated (4) Divorced (5) Single (never been married) (6) Widowed		
Living alone	(0) No (1) Yes		
Employment status	(1) Employed / Self employed (2) Retired/Not working		
Deprivation index (ID2004)		(1-4) Quartiles	ID 2004

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Ethnic group (2001 census presentation for England and/or Wales)	(1) White: British, Irish, Any Other White background. (2) Mixed: White and Black Caribbean, White and Black African, White and Asian, Any Other Mixed background. (3) Asian or Asian British: Indian, Pakistani, Bangladeshi, Any Other Asian background. (4) Black or Black British; Caribbean, African, Any Other Black background. (5) Chinese or Other ethnic group: Chinese, Any Other ethnic group.		
Diabetes	(0) Not Diabetic (1) Diabetic	(0) No: Patient does not have diabetes. (1) Diet-controlled: The patient has received dietary advice appropriate to their condition but is not receiving medication. (2) Oral therapy: The patient uses oral medication to control their condition. (3) Insulin dependent: The patient uses insulin treatment, with or without oral therapy, to control their condition.	
		(0) Not Diabetic (1) Diet-controlled or oral therapy (2) Insulin dependent	
Hypertension	(0) No (1) Yes: Treated or BP>140/90 on >1 occasion prior to admission.		

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Renal function	(0) No Renal Impairment (1) Renal Impairment: functioning transplant/creatinine>200 umol/l/acute or chronic renal failure.	(0) No: No history of renal disease and creatinine < 200 micro moles/litre at start of operation) (1) Functioning transplant: Functioning renal transplant, irrespective of creatinine. (2) Creatinine > 200 umol/l: Creatinine > 200 micro moles/litre at the time of operation. (3) Acute renal failure: Dialysis for acute renal failure: onset within 6 weeks of cardiac surgery. (4) Chronic renal failure: Continuing dialysis commencing more than six weeks before operation.	
Ejection fraction		(1) Poor (< 30%) (2) Fair (30-49%) (3) Good (> 49%)	
Previous M.I		(0) None (1) One (2) Two or more	

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Dyspnoea New York Heart Association (NYHA) classification.		(1) NYHA 1: No limitation of physical activity. Patients with cardiac disease but without limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitations or dyspnoea. (2) NYHA 2: Slight limitation of ordinary physical activity. Cardiac disease resulting in slight limitation of physical activity. They are comfortable at rest. Ordinary physical activity results in fatigue, palpitations or dyspnoea. (3) NYHA 3: Marked limitation of ordinary physical activity. Cardiac disease resulting in marked limitation of physical activity. They are comfortable at rest. Less than ordinary physical activity results in fatigue, palpitations or dyspnoea. (4) NYHA 4: Symptoms at rest or minimal activity. Cardiac disease resulting in an inability to conduct any physical activity without discomfort. Symptoms of cardiac failure may be present even at rest. If any physical activity is undertaken discomfort is increased.	

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Angina classification Canadian Cardiovascular Society (CCS) grading system.		(0) CCS 0: No angina. The patient has no history of angina. (1) CCS 1: No limitation of physical activity. Ordinary physical activity such as walking or climbing stairs does not cause angina. Angina may occur with strenuous, rapid or prolonged exertion. (2) CCS 2: Slight limitation of ordinary activity. There is slight limitation of ordinary activity, angina may occur on walking or climbing stairs rapidly, walking up hill or walking after meals, in the cold, wind or under emotional stress or climbing more than one flight of stairs under normal conditions. (3) CCS 3: Marked limitation of ordinary physical activity. There is marked limitation of ordinary physical activity, angina may occur after walking 100 yards or climbing one flight of stairs under normal conditions at a normal pace. (4) CCS 4: Symptoms at rest or minimal activity. Inability to perform any physical activity without discomfort. Angina may occur at rest.	
Peripheral vascular disease	(0) No (1) Yes		
Pulmonary disease	(0) No (1) Chronic Obstructive Airways Disease/Emphysema/ Asthma	(0) No (1) Chronic Obstructive Airways Disease/Emphysema: Patient requires medication (inhalers, aminophylline or steroids) for chronic pulmonary disease or FEV1 less than 75% predicted value. Venous pO2 < 60mmHg, pCO2 > 50mmHg). (2) Asthma: Intermittent or allergic reversible airways disease treated with bronchodilators or steroids.	

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Smoking history	(0) Never Smoked: Patient has never smoked cigarettes. (1) Ex-Smoker: Patient has smoked one or more cigarettes per day in the past but not within the last month. (2) Current Smoker: Patient regularly smokes one or more cigarette per day or has smoked in the last month.		
Left main stem coronary artery disease	(0) No LMS disease <51% diameter stenosis (1) LMS disease >50% diameter stenosis		
Number of vessels bypassed		(1-5) 1-5	No of vessels
Parsonnet score from hard data		(1) 0-4 (1% low risk) (2) 5-9 (5% elevated risk) (3) 10-14 (9% significantly elevated risk) (4) 15-19 (17% high risk) (5) >19 (31% very high risk)	Score
Parsonnet score with catastrophic states and other rare circumstances)		(1) 0-4 (1% low risk) (2) 5-9 (5% elevated risk) (3) 10-14 (9% significantly elevated risk) (4) 15-19 (17% high risk) (5) >19 (31% very high risk)	Score
EuroSCORE		(1) 0-2 (low risk) (2) 3-5 (moderate risk) (3) ≥ 6 (high risk)	Score

VARIABLE	NOMINAL DATA	ORDINAL DATA	INTERVAL DATA
Urgency of surgery	(1) Elective: Routine admission from the waiting list. (2) Non-elective: Urgent, emergency or salvage.	(1) Elective: Routine admission from the waiting list. (2) Urgent: Patients who have not been scheduled for routine admission from the waiting list but who require intervention or surgery on the current admission for medical reasons. They cannot be sent home without procedure. (3) Emergency: Unscheduled patients with ongoing refractory cardiac compromise. There should be no delay in surgery/intervention irrespective of the time of day) (4) Salvage: Patients requiring cardiopulmonary resuscitation en route to the operating theatre or prior to the induction of anaesthesia.	
Time on the waiting list		(0) Not on the waiting list (1) 0-3 months (2) > 3 months	
Preoperative length of stay		(1) 0-1day (2) 2-7 days (3) More than 1 week	
Hospital site	(1) Hospital 1 (2) Hospital 2		
Consultant	(1-11) A-K		
Cardiopulmonary bypass	(0) No (1) Yes		
Day of the week on which the 5th postoperative day occurred	(1) Sunday (2) Monday (2) Tuesday (4) Wednesday (5) Thursday (6) Friday (7) Saturday		

5.3.3 Phase II

Data were collected using the same methods described for Phase I for the cohort identified.

Perceived stress and health locus of control were included in this Phase of the study following their identification as potentially important variables using the theoretical framework applied to the study in chapter two.

Patients from the cohort who attended preadmission clinic were given a verbal description of the study, followed by a written patient information sheet. Informed consent to participate in the investigation of perceived stress and health locus of control on PLOS was then obtained.

Consenting patients were asked to complete the PSS and the MHLC scale in the preadmission clinic by the investigator or designated signatory (preadmission nurse). The Patient Information Sheet, consent form, PSS and MHLC scale are presented in appendix 3.

5.3.3.1 The Perceived Stress Scale.

The PSS (Cohen et al, 1983) is theoretically congruent with the transactional definition of stress proposed by Lazarus and Folkman (1984) and is based on the work of Lazarus (1966; 1977).

The ten-item PSS (Cohen and Williamson, 1988) is a widely used instrument to measure the degree to which situations are appraised as stressful. The items refer to the individual’s feelings and thoughts during the last month and measures how unpredictable, uncontrollable, and overloaded a person finds their life, all of which have been identified as central components of the experience of stress (Cohen et al, 1983). The patient responses are measured using a five-point Likert-style response scale: (0 = never, 1 = almost never, 2 = sometimes, 3 = fairly often, and 4 = Very often).

The items are free of content specific to any sub-population and scores are obtained by reversing responses to the four positively stated items (4, 5, 7 and 8) and then summing across all ten items. Scores range from 0-40 where the higher the score, the more perceived stress. Missing values were imputed using the item mean.

The PSS has established reliability and validity (r = 0.85). Cohen and Williamson (1988) showed correlations with the PSS and stress measures, self-reported health and health services measures, health behaviour measures, smoking status and help seeking behaviour. The PSS also has strong internal reliability with a Cronbach's alpha of 0.78 (Cohen and Williamson, 1988).

Test-Retest reliability and predictive validity is strongest for shorter time periods. Congruent with the perspective of Lazarus and Folkman (1984) the levels of appraised stress should vary as the person interacts with the environment and changes in coping resources, therefore the predictive validity of the PSS is expected to decrease after four to eight weeks.

The PSS has been used to measure stress in many studies across a variety of settings including CABG, see for example Barry et al (2006), Ellard et al (2006).

5.3.3.2 Multidimensional Health Locus of Control Scale

The MHLC scale (Wallston et al, 1978) measures generalised expectancy beliefs with respect to health along three dimensions: internal, external - chance or fate, and external - powerful others. The internal dimension refers to the extent to which individuals believe their health is the result of their own actions. The external dimensions include chance or fate, referring to the extent to which individuals believe their health is owing to chance or fate, and powerful others, referring to the extent to which individuals believe their health is a result of powerful others such as health care professionals.

Form B of the MHLC measures general health locus of control beliefs and contains three six-item subscales; internality (items 1, 6, 8, 12, 13, 17), chance externality (items 2, 4, 9, 11, 15, 16), and powerful others externality

(3, 5, 7, 10, 14, 18). The score on each subscale is the sum of the values circled for each item on the subscale. All the subscales are independent of one another.

As recommended by Wallston (1993), missing data was handled in one of two ways. Where no more than two items on a subscale were missing, a subscale score was calculated using the mean score for the subscale items that were not missing and multiplying the mean item score by six. Where more than two items were not responded to, the whole subscale was treated as missing.

The MHLC scales have been used in many studies across a variety of settings and have established reliability and validity. The reliability of the instrument as assessed by internal consistency is moderate, with a Cronbach alphas in the 0.60 - 0.75 range and test-retest coefficients ranging from 0.60 - 0.70 (Wallston, 1993). The MHLC scales have frequently been used to measure health locus of control beliefs in CABG patients, see for example Shelley and Pakenham (2007) and Barry et al (2006).

5.4 DATA ANALYSIS

The data was imported into and analysed using the Statistical Package for the Social Sciences (SPSS) version 13 for Windows (SPSS Inc., 2005) according to the aims and hypotheses stated on p171-172. The level of significance was established at the conventional level of $p \leq 0.05$ for a two-tailed test, in order to reject the null hypotheses (H_0). Subsequently, the probability of rejecting H_0 when it was true, the probability of a Type I error (α), was at most one in 20.

5.4.1 Phase I

5.4.1.1 Summary Statistics

Descriptive statistics were used to explore the assumption that a group of patients would be discharged within five days of first time isolated CABG.

The mean, median and mode day of discharge were calculated together with the percentage of patients achieving discharge within five postoperative days. Summary statistics for each of the independent variables were presented as the mean and standard deviation for all continuous variables. Numbers and percentages were given for all categorical variables. The continuous and categorical variables are listed in table 5.4.1.1.1

Before hypothesis testing, the distribution of all continuous variables and the distribution within each level of all categorical variables were tested for normality in order to ensure the appropriate selection of either parametric or non-parametric tests. The one-sample Kolmogorov-Smirnov test was used to compare the observed distribution with a theoretical normal distribution.

It was anticipated that the distribution of PLOS would be positively skewed and non-normal (Austin et al, 2002). Consequently, a natural log transformation, before and after the removal of outlying values, was performed in order to obtain a more normal distribution and the tests for normality were repeated. The distribution of PLOS was also compared with a theoretical Poisson distribution as this has previously been used to determine the risk factors associated with increased PLOS following CABG and to calculate risk-adjusted PLOS (Naylor et al, 1999 cited by Austin et al, 2002).

In the event of the continuous variables being normally distributed and equal variance among the groups, parametric tests based on normal distribution theory were selected due to their superior power to nonparametric tests in these circumstances (Siegal and Castellan, 1988). Generally, nonparametric tests incur a loss of power for a given sample size if the assumptions of a parametric test are met, increasing the chance of a Type II error (Siegal and Castellan, 1988). In the event of violations of the assumptions underlying the use of the parametric tests, alternative nonparametric statistics were considered appropriate. Nonparametric tests do not make assumptions about the distribution of the population or its parameters and reduce the influence of outliers.

TABLE 5.4.1.1.1:
CONTINUOUS AND CATEGORICAL VARIABLES

Continuous Variables	Categorical Variables		
	2 levels (nominal)	>2 levels	
		Nominal	Ordinal
• Age • Body Surface Area • Body Mass Index • ID2004 • Parsonnet score (hard data and with catastrophic states and other rare circumstances included) • EuroSCORE	• Gender • Living alone • Ethnic group • Diabetic classification • Hypertension • Renal disease • Previous myocardial infarction • Peripheral vascular disease • Pulmonary disease • Left main stem disease • Urgency of operation • Hospital site • Cardiopulmonary bypass	• Marital status • Employment • Ethnic group • Smoking history • Consultant	• Age category • Body surface area category • Body mass index category • ID2004 quartiles • 3 & 4 Diabetic classifications • Ejection fraction • Previous myocardial infarction • Dyspnoea classification • Angina classification • Parsonnet risk category • EuroSCORE risk category • Number of vessels bypassed • Urgency of operation • Time spent on the waiting list • Preoperative length of stay

For each parametric test, H_0 stated that the group means were equal and the observed difference was due to random error. The research hypothesis (H_1) stated that the group means were not equal and the independent variable was observed to have an effect.

If nonparametric tests were selected H_0 stated that the groups had the same distribution, whilst H_1 stated that there were differences observed among the groups, where at least one pair of groups differed with regards to the underlying distribution of PLOS.

5.4.1.2 Univariate and multivariate analyses

A univariate analysis of each single independent variable with both PLOS as a continuous variable (hypothesis 1) and as a categorical dichotomy (hypothesis 2) was first performed for all 31 independent variables. Multivariate analyses were then used to explore the combined significance of variables that were statistically significant by univariate analysis, and derive mathematical equations for the purpose of predicting PLOS as a continuous variable (hypothesis 3) and as a categorical dichotomy (hypothesis 4).

Predicting postoperative length of stay as a continuous variable

All continuous independent variables were tested for statistical association with PLOS using the Pearson correlation coefficient or the Spearman rank correlation coefficient. The strength of the relationship or size of effect was determined as follows; $r \geq .70$ = very large, $r = .50$ = large, $r = .30$ = medium, $r = .10$ = small (Cohen, 1988).

Categorical independent variables with two levels were tested for differences between the groups and PLOS using the independent samples t-test or the Mann-Whitney U test.

Categorical variables with more than two levels were tested for differences between the groups and PLOS using the one-way analysis of variance (ANOVA) or the Kruskal Wallis test.

Post hoc multiple comparisons using either t-tests or the Mann-Whitney U test were used to determine which groups differed. To correct for multiple comparisons and avoid inflating the type I error rate, the Bonferroni adjustment method was used whereby the adjusted α level for a given single test is obtained by dividing the required α value by the number of comparisons.

This is a conservative method to reduce the type I error rate (the probability of rejecting the null hypothesis, when it is true) which increases the risk of a type II error (the probability of accepting a null hypothesis, when it is false) (Perneger, 1998). This means that significant results may be lost and the power of the study reduced. A variable was therefore only omitted from the multivariate tests when all the comparisons for that variable were not significant.

Following the univariate analysis, a multivariable one-way ANOVA was used to construct two statistical models to describe the relationship between PLOS and a combination of multiple independent variables that were either continuous or categorical using the general linear model. Model 1 was developed using continuous levels of measurement of the independent variables where possible. Model 2 was developed using categorical levels of measurement of the independent variables where possible. Only preoperative patient variables that were independently associated with PLOS as a continuous variable by univariate analysis, and therefore considered “a priori” influential, were included in the model.

Post hoc tests for significant variables with more than two levels were conducted using Scheffé’s pairwise comparison procedure to control the type I error rate. Dunnet’s C procedure was selected for where equal variance was not assumed. Levene's test was used to test the hypothesis that the variances of each group were equal. The standardised residuals were then examined for normality.

Predicting postoperative length of stay as a categorical dichotomy

To test for differences in PLOS as a categorical dichotomy and all continuous independent variables, the independent samples t-test or the Mann-Whitney U test was used.

To test for an association between PLOS as a categorical dichotomy and each categorical independent variable, a two-way cross tabulation was used to examine the relationship. The Pearson Chi-square test was used to test for statistical association.

The phi (φ) co-efficient was used to measure the strength of an association between PLOS as a categorical dichotomy and nominal level independent variables which formed a 2x2 table. The Cramér coefficient (Cramér's V) was used to measure the strength of an association for nominal level variables which formed larger tables. Kendall's tau-c (τ) was used to measure the strength of an association in larger tables where the categories were ordered. Again, the strength of the relationship was judged using the values of r as suggested by Cohen (1988).

Following univariate analysis, binary logistic regression was used to construct two statistical models to describe the relationship between PLOS as a categorical dichotomy and a combination of multiple independent variables that were either continuous or categorical. Model 3 was developed using continuous levels of measurement of the independent variables where possible. Model 4 was developed using categorical levels of measurement of the independent variables where possible. Only independent variables for which the H_0 was rejected and for which it was accepted that PLOS within five days varied as a function of the independent variable by univariate analysis were included.

To limit the number of predictor variables in the regression equation and increase parsimony, a stepwise method using conditional backward selection was used. The Nagelkerke pseudo r-square statistic was used to measure the amount of variation that was explained by the model and the Hosmer and Lemeshow goodness-of-fit test (Hosmer and Lemeshow, 1989) was used to test whether the combination of variables in the model adequately fitted the data.

A classification table comparing the predicted and observed outcomes was used to assess the specificity and sensitivity of the model. Sensitivity measured how well the model performed in identifying patients with a PLOS of five days or less. Specificity measured how well the model performed in identifying patients with a PLOS greater than five days.

Where patients with a PLOS greater than five days were incorrectly classified as PLOS of five days or less a type I error was made. Where patients with a PLOS of five days or less were incorrectly classified as PLOS greater than five days a type II error was made. The researcher subjectively accepted the step which achieved the highest sensitivity. This subjectivity reflected the desire to maximise the number of patients correctly identified with PLOS of five days or less and lower the type II error. The rationale for this decision was based on the reasoning that where a type I error was made, the patient's discharge date would automatically be reviewed on the fifth postoperative day but if a type II error was made, the patient's discharge could potentially have been delayed for non clinical reasons. Hence, this decision would maximise the number of patients efficiently discharged within five days and minimise the number of delayed discharges. This is important for both the speed and quality of the patient journey and maximises the utility of the model. Lower thresholds for predicted PLOS of five days or less were also evaluated.

The significance of each variable in the final model was examined using likelihood ratio tests and 95% confidence intervals for the odds ratios for each variable. The area under the receiver operator characteristic (ROC) curve (c-statistic) was also used to evaluate the performance of the models.

Finally, the standardised residuals were tested for normality and examined to see how well the model fitted the data, and to isolate points for which the model had a poor fit and points that exerted an undue influence on the model using Cook's statistic.

For both multivariate analyses a number of measures were taken to avoid problems with multi-collinearity. Multi-collinearity occurs when two or more explanatory factors are strongly related with one another and may result in large standard errors that mean the correct estimate of their independent effects on the outcome is not obtained (Ostir and Uchida, 2000). Where a variable had more than one classification that was independently associated with PLOS as a continuous variable or dichotomy, the classification which provided the best power to identify trends was selected. In addition, the Parsonnet score from hard data was included in favour of the subjective Parsonnet score with catastrophic states and other rare circumstances. Variance inflation factor (VIF) statistics were calculated to test for multi-collinearity between the remaining variables.

For the univariate analysis, all significant differences in PLOS for categorical variables with more than two groups were illustrated graphically. All significant associations with PLOS as a categorical dichotomy were presented graphically by means of a stacked bar chart.

Table 5.4.1.2.1 summarises the statistical tests used in the univariate analysis.

TABLE 5.4.1.2.1:
SUMMARY TABLE OF STATISTICAL TESTS USED IN THE UNIVARIATE ANALYSIS

Variable level of measurement	**PLOS** Parametric	Nonparametric	**Dichotomised PLOS**
Categorical 2 Levels	t-Test	Mann-Whitney U	Pearson chi-square Phi (φ)
> 2 Levels	One-way ANOVA with post-hoc t-tests	Kruskal Wallis with post-hoc Mann-Whitney tests	Pearson chi-square Cramér's V or Kendall's tau-c (τ)
Interval	Pearson Correlation (r)	Spearman Rank Correlation (r_s)	t-Test or Mann-Whitney U

5.4.2 Phase II

The effectiveness of models 1 and 2 to accurately predict PLOS was tested using the paired samples t-test. Where the assumptions of the t-test were not met, the nonparametric Wilcoxon Signed Ranks test was used.

The effectiveness of models 3 and 4 to accurately predict discharge within five days of surgery was tested using the McNemar test. The area under the ROC curve was also used to evaluate the calibration of the logistic regression models in the validation sample.

A univariate analysis of the PSS and the MHLC scales was performed using the same procedure for the univariate analysis of the variables in Phase I. Variables identified as significant by univariate analysis were then entered as a second step into the original respective models and the models re-evaluated as previously described.

5.4.3 Description of the tests

The one-sample Kolmogorov-Smirnov test

The one-sample Kolmogorov-Smirnov test is used to test the null hypothesis that the sample could reasonably have come from a specified theoretical distribution. It assumes interval or ratio level of measurement (SPSS, 2005).

To test the assumption of normality, this goodness-of-fit test compares the observed cumulative distribution function with a theoretical normal distribution where H_0 stated that the observed cumulative distribution expected was normal and H_1 stated that the observed cumulative distribution expected was not normal.

Levene's Test

Levene's test tests the assumption of homogeneity of variance. For each dependent variable, an analysis of variance is performed on the absolute deviations of values from the respective group means (StatSoft, 2006).

H_0 states that the difference between the variances is zero and H_1 states that the variances of each group are equal. A non significant result indicates that the assumption has been met (SPSS, 2005).

The independent samples t-test

The independent samples t-test is a parametric test that compares the difference between two independent group means with the standard error of the difference between the means of different samples (Bryman and Cramer, 1997). Parametric tests assume interval data, a normal distribution, and homogeneity of variance.

The Mann-Whitney U test

The Mann-Whitney U test (Mann and Whitney, 1947) tests the null hypothesis that two samples have the same distribution. It is the nonparametric equivalent of the t-test used when the assumptions are not met.

One-way analysis of variance

The one-way ANOVA is a parametric test that tests for differences between more than two group means. It is robust from departures of normality although data should be symmetric and the groups should come from populations with equal variances (SPSS, 2005).

The Kruskal-Wallis H test

The Kruskal-Wallis H test (Kruskal and Wallis, 1952) is a nonparametric alternative to one-way ANOVA when the assumptions have not been met (Kinnear and Gray, 1999). It is used to compare three or more samples and tests the null hypothesis that the different samples in the comparison were drawn from the same distribution or from distributions with the same median (StatSoft, 2006).

The Pearson correlation coefficient

The Pearson correlation coefficient (r) is a parametric test to measure the strength and direction of a linear association between two interval or ordinal variables. It assumes a pair of variables is bivariate normal. Values range between zero and one, with zero indicating no association and values close to one indicating a high degree of association between the variables (SPSS, 2005).

The Spearman rank correlation coefficient

The Spearman rank correlation coefficient (r_s) is a nonparametric alternative to the Pearson correlation coefficient that measures the rank-order association between two variables measured on at least an ordinal scale (SPSS, 2005).

The Pearson Chi-square test

Following a two-way cross tabulation of observed and expected cell counts, the Pearson Chi-square test measures the independence of one nominal variable against another by measuring the discrepancy between the observed cell counts and what would be expected if the rows and columns were unrelated. Values range between zero and one, with zero indicating no association between row and column variables and values close to one indicating a high degree of association between the variables (SPSS, 2005). The H_0 states the row and column variables are independent or unrelated whilst H_1 states the row and column variables are not independent.

The use of the Chi-square test assumes that in 2x2 tables, all expected counts should be greater than five. Cochran (1954) cited by Siegal and Castellan (1988) recommended that when the degrees of freedom are greater than one, no more than 20% of the cells should have an expected frequency of less than five, and no cell should have an expected frequency of less than one.

Where these requirements are not met by the data, and cannot be meaningfully achieved by combining categories, the Fisher's exact test and the likelihood ratio are alternatives for 2x2 and larger tables respectively (Siegal and Castellan, 1988).

The Phi, Cramér and Kendall rank order correlation coefficients

The Phi, Cramér and Kendall rank order correlation coefficients are correlation tests for 2x2, larger unordered, and ordinal contingency tables respectively, based on the Chi-square distribution.

The Phi coefficient (r_φ) is a measure of the extent of the association or relation between two sets of attributes measured on a nominal scale, each of which may take on only two values (Siegal and Castellan, 1988). It is the ratio of the Chi-square statistic to the total number of observations, calculated by dividing the

Chi-square statistic by the sample size and taking the square root of the result. It is the most optimistic of the symmetric measures but it does not have a theoretical upper boundary when either of the variables has more than two categories because the Chi-square value can exceed the sample size.

The Cramér coefficient is a measure of the degree of the association or relation between two sets of unordered categorical variables that enables the comparison of larger contingency tables (Siegal and Castellan, 1988). It is a rescaling of Phi so that its maximum possible value is always one. When both variables have only two categories Phi and Cramér's V are identical but as the number of rows and columns increases, Cramér's V can attain its maximum value of one and so becomes more conservative with respect to Phi.

The Kendall rank order correlation coefficient, referred to as Kendall's tau-c (τ) is a measure of the degree of association or correlation where the measurement of both variables is ordinal and each case can be assigned a rank for each variable (Siegal and Castellan, 1988).

A Phi, Cramér, or Kendall's tau-c coefficient with a value less than 0.3 is considered to indicate that the relationship between two variables is not very strong, even if it is not likely to be due to chance.

The General Linear Model

The general linear model is a generalisation of the linear regression model, such that effects can be tested for categorical and continuous independent variables with single or multiple dependent variables. The value of the dependent variable (Y) estimated from the value of two or more independent variables (X) is given by the equation in Figure 5.4.3.1.

FIGURE 5.4.3.1

Regression equation

$$Y = b_0 + b_1X_1 + b_2X_2 + ... + b_kX_k$$

Where the intercept b_0 is the regression constant, $b_{1,}\ b_{2,\ ...,}\ b_k$ are the regression coefficients, and k is the number of predictors (StatSoft, 2006).

The procedure assumes the data is normally distributed, there is equal variance between the groups and the factors and covariates have a linear relationship to the dependent variable. Austin et al (2002) recommended that generalised linear models, infrequently used in the clinical literature, should be considered for predicting PLOS for CABG.

Scheffe's Test

Scheffe's test is a post hoc test of multiple pairwise comparisons that can be used to determine the significant differences between group means in an analysis of variance setting (StatSoft, 2006).

Dunnet's C

Dunnet's C test is a post hoc test of multiple pairwise comparisons that can be used to determine the significant differences between a single control group mean and the remaining treatment group means in an analysis of variance setting (StatSoft, 2006).

Binary Logistic Regression

Binary logistic regression is used to predict the probability of a dichotomous outcome (Y) occurring, given known values of one or more continuous or categorical predictor variables (X_s). The logistic regression equation from which the probability of Y is predicted is given in Figure 5.4.3.2.

FIGURE 5.4.3.2:

Logistic regression equation

$$P(Y) = 1/ 1+e^{-z}$$

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon_i$$

Where P(Y) is the probability of Y occurring, e is the base of natural logarithms, β_0 is the Y intercept, β_1 is the gradient of the straight line, X is the value of a predictor variable, and ε is a residual term (SPSS, 2005).

The resulting value from the equation is a probability value that varies between zero and one. A value close to zero means that Y is unlikely to have occurred, and a value close to one means that Y is very likely to have occurred. Each variable in the equation has its own coefficient which was estimated using the maximum likelihood method which selects coefficients that make the observed values most likely to have occurred (SPSS, 2005).

The logistic regression equation expresses the multiple linear regression equation in logarithmic terms and therefore overcomes the problem of violating the assumption of linearity. However, logistic regression assumes linearity in the logit and additivity. Logistic regression does not assume normality but the model may be more stable if the independent variables have a multivariate normal distribution.

Logistic regression is a widely accepted statistical modelling technique for exploring the relationship between predictor variables and a categorical outcome that has been used in previous studies of CABG (Weintraub et al, 1989; Tu et al, 1995; Peterson et al, 2002; Anderson et al, 2006).

Stepwise Backward Selection

Stepwise selection methods are used to identify the variables with statistically significant effects for inclusion in regression models (Tabachnick and Fidell, 2001). When backward selection is used, each independent variable is removed one at a time from the model based on the level of statistical association between the independent and dependent variables (Morgan et al, 2003). Backward selection was chosen because there is a higher risk of making a type II error associated with forward selection which is more likely to exclude predictors involved in suppressor effects which occur when a predictor has a significant effect but only when another variable is held constant (Field, 2000).

Nagelkerke Pseudo r-Square Statistic

This is a R^2-like strength of association measure. It attempts to imitate the interpretation of multiple R-Square based on the likelihood, such that it can vary from zero to one (Garson, 2008).

Hosmer and Lemeshow Goodness-of-Fit Statistic

This is a goodness of fit statistic that is used for models that include continuous variables and small sample sizes. It is based on grouping cases into deciles of risk and comparing the observed probability with each decile (SPSS, 2005).

Likelihood Ratio Test

The likelihood-ratio test uses the ratio of the maximized value of the likelihood function for the full model over the maximized value of the likelihood function for a reduced model. A non significant likelihood ratio test indicates no difference between the full and the reduced model, and may justify removing the given variable from the model to achieve a more parsimonious model (Garson, 2008).

Odds Ratio (OR)

The odds of an outcome refers to the probability that the outcome occurs divided by the probability that it does not. The odds ratio for a predictor tells the relative amount by which the odds of the outcome increase (OR greater than 1.0) or decrease (OR less than 1.0) when the value of the predictor value is increased by 1.0 unit. The 95% confidence interval is used to examine the statistical significance of an odds ratio. If the confidence interval does not include 1.00 the null hypothesis is rejected (Ostir and Uchida, 2000).

Cook's Statistics

Cook's statistics are used to check for influential data points in regression analyses. They show the shift in the estimated parameter from fitting a regression model when a particular case is omitted (SPSS, 2005). Relatively large Cook statistics indicate influential observations.

Variance Inflation Factor

The VIF indicates whether a predictor has a strong linear relationship with the other predictors. If the VIF is greater than ten then there is cause for concern. If the average VIF is substantially greater than one then the regression may be biased (Field, 2000).

Paired Samples T-Test

The paired samples T-test is used to test the difference between the means of two related samples. It is a parametric test that assumes that the data is normally distributed with equal variance (SPSS, 2005).

Wilcoxon Signed Ranks Test

This is a nonparametric alternative to the paired samples T-test. It tests the null hypothesis that two related medians are the same. The test assumes that the population distribution of the paired differences is symmetric (SPSS, 2005).

McNemar Test

The McNemar test is used test marginal homogeneity in K×K tables. It tests the null hypothesis of no difference between two related samples of nominal or ordinal data. A significant result implies that marginal frequencies (or proportions) are not homogeneous (SPSS, 2005).

Receiver Operator Characteristic (ROC) Curve

This is a graphical method to evaluate the performance of a classification model for a dichotomous outcome. The ROC curve plots the false positive rate (1 – specificity) on the X axis and the true positive rate (sensitivity) on the Y axis, showing the trade-off between the two (SPSS, 2005).

The C-Statistic

The c-statistic is equal to the area under the ROC curve and is generated from the sensitivity and specificity measurements of dichotomous outcomes. In general, values less than 0.7 are considered to show poor discrimination, values of 0.7-0.8 are considered reasonable, and values above 0.8 good (Aylin et al, 2007).

In the current study discrimination refers to the probability of assigning a greater chance of discharge within five days to a randomly selected patient who was discharged within five days compared with a randomly selected patient who was not discharged within five days. A value of 0.5 suggests that the model is no better than random chance in predicting discharge within five days whilst a value of 1.0 suggests perfect discrimination.

5.5 Ethical Approval

Ethical approval for the study was obtained from a Local Research Ethics Committee (LREC).

Patient consent was not obtained for Phase I because this was impractical and may have resulted in a selection bias and subsequent flawed results. To remain anonymous, all patients within the study were identified by their medical record number within the spreadsheet. No actual patient names appeared in the spreadsheet or the final thesis.

Whether the disclosure of even fully anonymised data, without the consent from every individual constitutes a breach of the duty of confidence owed to patients is widely debated in the medical literature (Walton et al, 1999). However, several authors consider the secondary use of anonymised data for observational research does not result in harm to the individual and therefore does not require consent (Warnock, 1998; Al-Shahi and Warlow, 2000; Willison et al, 2003; Dawson, 2004; Fox, 2004).

The risks to the security of patient information posed by electronic records and data handling in the NHS has lead to the revision of legislation and professional guidance to safeguard the patient's right to privacy and to which healthcare professionals who wish to use patient data for research must adhere (The Caldicott Committee, 1997; The Data Protection Act, 1998; The Information Commissioner, The Human Rights Act, 1998; The Health and Social Care Act, 2001: Department of Health, 2002b).

Permission to retrieve the data was obtained in advance from those responsible for data protection, including the Lead Clinician of the Cardiac Directorate, the Trust Data Protection Officer and the LREC. It was not anticipated that contact would be made with patients as a result of the research findings.

In Phase II, the voluntary nature of completing the PSS and MHLC scales was made clear to patients within all communications and patients were informed that they had the freedom to withdraw, or choose not to participate without influencing their current or future medical or nursing care. Patients were also informed that participation would not lengthen or shorten their PLOS.

There were no significant risks associated with the study process and no costs to the participants were anticipated for participating in the research project. It was anticipated that usual clinical practice would not change during the period of data collection.

The study was financially supported by the Research and Development Department of the researcher's Trust who provided constructive feedback on the funding application but played no part in the study design, data collection, or analysis and interpretation of the data.

CHAPTER 6

RESULTS

The results of the study are organised into four sections. Section 6.1 describes the samples, the distribution of PLOS and the percentage of patients who achieved discharge within five days of surgery in Phase I and Phase II. Section 6.2 presents the results of the univariate analyses testing hypotheses 1 and 2. The results of the multivariate prediction analyses testing hypothesis 3 and 4 are presented in section 6.3 along with the validation of the resultant models. The results of the analysis of the psychological variables are presented in section 6.4.

6.1 DESCRIPTIVE STATISTICS

6.1.1 Phase I

The sample consisted of 1057 patients. During the period of data collection 14 patients (1.3%) died in hospital and were subsequently excluded from the statistical tests. PLOS for patients excluded ranged from zero to 42 days. A total of 1043 patients were discharged from hospital alive or transferred to another hospital to continue their recovery. These patients were included in the statistical tests.

The mean age of this sample was 66.7 years (sd 9.3 years) and consisted of 838 (80.3%) male patients and 205 (19.7%) female patients. Surgery was performed without CPB for 132 (12.7%) patients whilst 824 (79%) of patients received conventional CABG with CPB. Elective surgery was performed for 756 (72.5%) patients whilst 287 (27.3%) patients underwent urgent, emergency or salvage operations. The majority of patients (n = 707, 66.3%) were admitted on the day of or the day before surgery and had been on the waiting list for less than three months (n = 636, 61%).

The PLOS for all patients either transferred or discharged from hospital alive ranged from three to 242 days. The mean, median, and modal PLOS were 8.20 days (s.d. 10.06 days), six days (IQR 5-8 days) and five days respectively. The distribution of PLOS is presented in Figure 6.1.1.1 and shows a clear modal value of five days but also a positively skewed long tail representing prolonged PLOS.

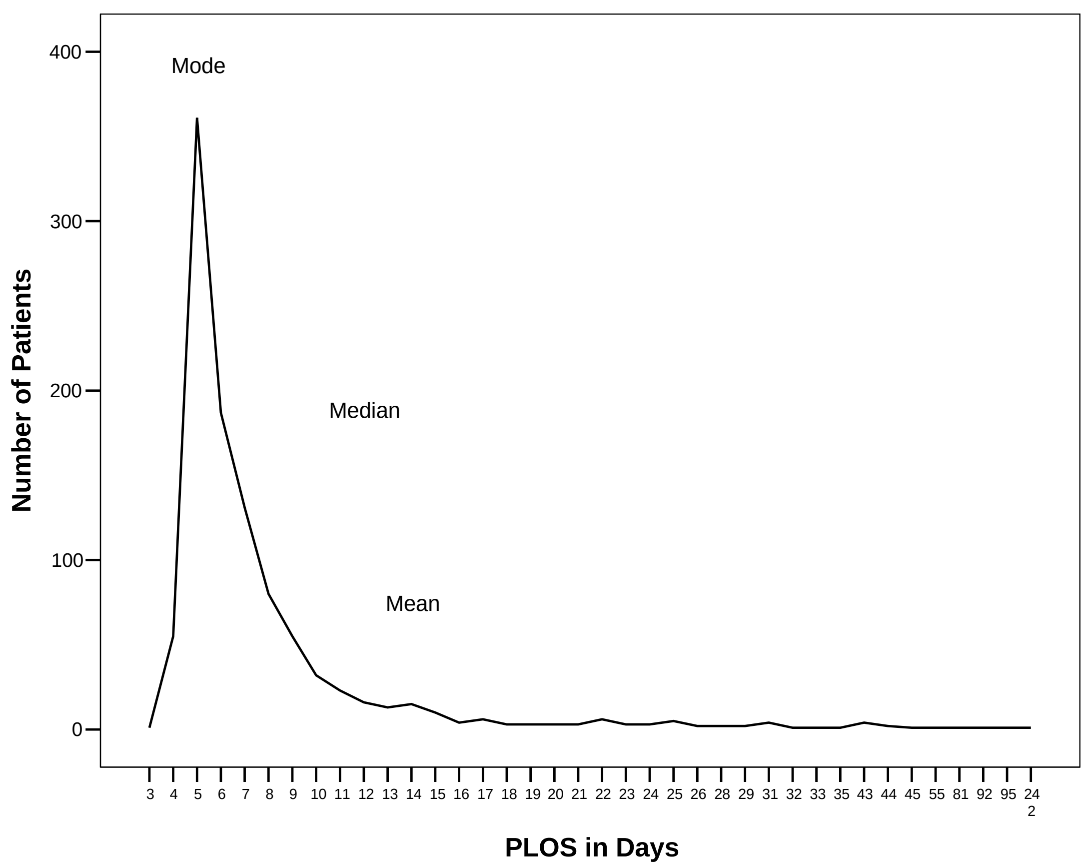


FIGURE 6.1.1.1:

The distribution of postoperative length of stay

Preliminary exploration of the data indicated that the assumptions of the parametric tests had been seriously violated. The distribution of PLOS was not normal (K-S Z = 10.89, $p < 0.001$), and a natural log transformation failed to obtain a more normal distribution (K-S Z = 6.33, $p < 0.001$). Figure 6.1.1.2 shows the distribution of the natural log of PLOS.

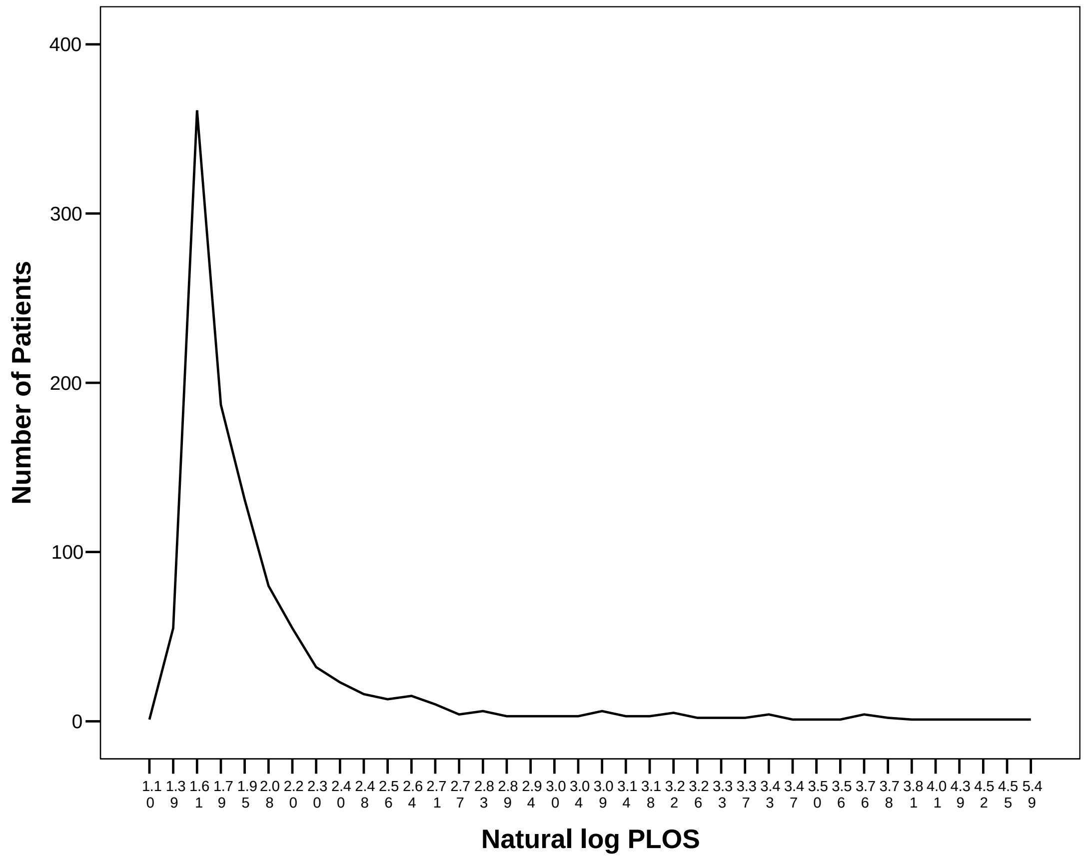


FIGURE 6.1.1.2:

The distribution of the natural log of postoperative length of stay

The undue influence of outliers was indicated by a high mean value in comparison to both the median and the mode. Neither the removal of outliers, with a PLOS of 13 days or more, or a log transformation of the remaining sample, sufficiently improved normality (K-S Z = 6.64, $p < 0.001$ and K-S Z =

6.82, $p < 0.001$ respectively). PLOS did not resemble a Poisson distribution (K-S Z = 9.36, $p < 0.001$). As the distribution of PLOS did not meet the assumptions of the parametric tests, alternative nonparametric tests were selected because they do not assume normality and reduce the influence of outliers.

Linear models are generally robust to violations of the assumptions of normality and equal variances between the groups but the results are sensitive to the presence of outliers. The removal of outliers did improve the symmetry of the distribution. Skewness, or the asymmetry of the distribution, reduced to 1.18 compared to 14.18, and kurtosis (the concentration about the mean), reduced to 0.89 from 292.56. For this reason, outliers with a PLOS greater than 12 days were removed for the modelling of PLOS only.

A total of 417 patients (40%) were discharged within five days of surgery, compared to 626 patients (60%) who were discharged after five days. Figure 6.1.1.3 illustrates the proportion of discharges within five days of surgery.

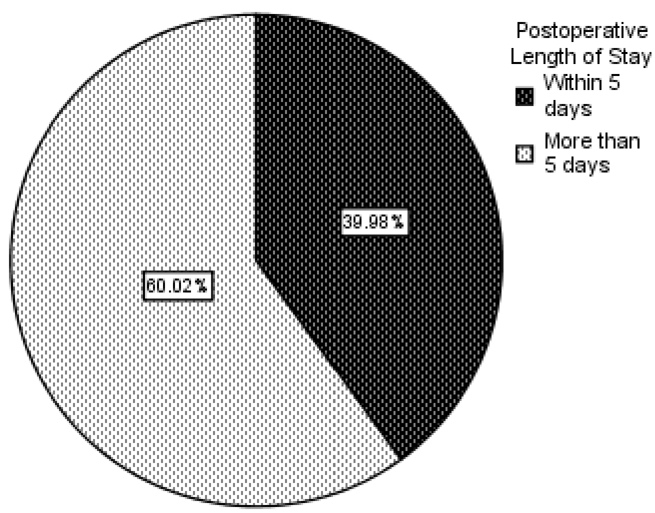


FIGURE 6.1.1.3

The proportion of discharges within five days of CABG.

6.1.2 Phase II

The validation sample consisted of 509 patients. A total of six patients (1.2%) died in hospital and were subsequently excluded from the statistical tests. PLOS for patients excluded ranged from one to 65 days. The remaining sample consisted of 503 patients who were discharged from hospital alive or transferred to another hospital to continue their recovery.

The mean age of this sample was 65.2 years (s.d. 10.5 years) and consisted of 408 (81.1%) male patients and 95 (18.9%) female patients. Surgery was performed without CPB for 54 (10.7%) patients whilst 421 (83.7%) of patients received conventional CABG with CPB. Elective surgery was performed for 319 (63.4%) patients whilst 183 (36.4%) patients underwent urgent, emergency or salvage operations. The majority of patients (n = 356, 70.8%) were admitted the day of or the day before surgery and had been on the waiting list for less than three months (n = 324, 64.4%).

The PLOS for all patients either transferred or discharged from hospital alive ranged from three to 105 days. The mean, median, and modal PLOS were comparable to Phase I at 8.21 days (s.d. 7.68 days), six days (IQR 5-8 days) and five days respectively. Again, the distribution of PLOS was not reasonably normal (K-S Z = 6.50, $p < 0.001$). The proportion of the sample that achieved discharge within five days of surgery remained unchanged with a total of 201 patients (40%) discharged within five days of surgery, and 302 patients (60%) discharged after five days.

Table 6.1.2.1 shows the characteristics of the patients included and excluded from the Phase I and Phase II samples, together with those of the population of patients who underwent CABG in NHS hospitals in Great Britain and Ireland as reported in the NACS Database Report of 2003 (Keogh and Kinsman, 2004).

TABLE 6.1.2.1:
THE CHARACTERISTICS OF THE PHASE I AND PHASE II SAMPLES TOGETHER WITH THE WIDER POPULATION OF 2003

Variable	Categories	NACS Database 2003 %	Deaths Phase I N (%)	Deaths Phase II N (%)	Phase I N	Phase I %	Phase II N	Phase II %
Sample		_	14 (1.3)	6 (1.2)	1043	98.7	503	98.8
Age Category	< 51years	32.4	1 (7.1)	0	58	5.6	52	10.3
	51-60 years		1 (7.1)	0	206	19.8	105	20.9
	61-70 years	39.1	5 (35.7)	2 (33.3)	369	35.4	164	32.6
	>70 years	28.1	7 (50.0)	4 (66.6)	410	39.3	182	36.2
	Missing	0.4	0	0	0	0	0	0
Gender	Male	80.0	11(78.6)	4 (66.6)	838	80.3	408	81.1
	Female	20.0	3 (21.4)	2 (33.3)	205	19.7	95	18.9
BSA	<1.70m^2	11.5	5 (35.7)	1 (16.6)	138	13.2	78	15.5
	1.70-1.89 m^2	29.7	4 (28.6)	2 (33.3)	359	34.4	176	35.0
	1.90-2.39 m^2	50.2	4 (28.6)	3 (50.0)	536	51.4	222	44.1
	>2.39 m^2				8	0.8		
	Missing	8.5	1 (7.1)	0	2	0.2	27	5.4
BMI Category	<20.0	21.3	7 (50.0)	1 (16.6)	20	1.9	141	28.0
	20.0-24.9				276	26.5		
	25.0-30.0	42.6	3 (21.4)	3 (50.0)	476	45.6	193	38.4
	30.1-40.0	26.9	3 (21.4)	2 (33.3)	252	24.2	142	28.2
	>40.0				17	1.6		
	Missing	9.2	1 (7.1)	0	2	0.2	27	5.4
Marital Status	Married/Co-habiting	*	9 (64.3)	3 (50.0)	736	70.6	364	72.4
	Separated/Divorce		0	0	71	6.8	21	4.2
	Single		1 (7.1)	0	52	5.0	37	7.4
	Widowed		1 (7.1)	1 (16.6)	103	9.9	51	10.1
	Missing		3 (21.4)	2 (33.3)	81	7.8	30	6.0
Living Alone	No	*	9 (64.3)	3 (50.0)	798	76.5	409	81.3
	Yes		2 (14.3)	1 (16.6)	133	12.8	57	11.3
	Missing		3 (21.4)	2 (33.3)	112	10.7	37	7.4

Variable	Categories	NACS Database 2003 %	Deaths Phase I N (%)	Deaths Phase II N (%)	Phase I N	Phase I %	Phase II N	Phase II %
Employment	Retired/unemployed	*	6 (42.9)	4 (66.6)	374	35.9	202	40.2
	Employed/self-employed		2 (14.3)	0	144	13.8	95	18.9
	Missing		6 (42.9)	2 (33.3)	525	50.3	206	41.0
Ethnic Group	White		7 (50.0)	4 (66.6)	731	70.1	320	63.6
	Mixed		0		6	0.6	2	0.4
	Asian or Asian Brit.	*	2 (14.3)		136	13.0	115	22.9
	Black or Black Brit.		0		13	1.2	11	2.2
	Chinese or Other ethnic group		0		9	0.9	11	2.2
	Missing		5 (35.7)	2 (33.3)	148	14.2	44	8.7
Diabetes	Not diabetic	77.2	11 (78.6)	5 (83.3)	744	71.3	315	62.6
	Diabetic	21.5	2 (14.3)	1 (16.6)	297	28.5	166	33.0
	Diet-controlled	*	2 (14.3)	1 (16.6)	62	5.9	102	20.3
	Oral therapy				139	13.3		
	Insulin therapy	*	0	0	96	9.2	64	12.7
	Missing	1.3	1 (7.1)	0	2	0.2	22	4.4
Hypertension	No	34.6	4 (28.6)	3 (50.0)	205	19.7	89	17.7
	Yes	63.9	9 (64.3)	3 (50.0)	835	80.1	392	77.9
	Missing	1.5	1 (7.1)	0	3	0.3	22	4.4
Renal Disease	No	87.4	11 (78.6)	5 (83.3)	1006	96.5	460	91.5
	Yes	1.4	2 (14.3)	1 (16.6)	32	3.1	21	4.2
	Missing	11.2	1 (7.1)	0	5	0.5	22	4.4
Ejection Fraction	Poor	5.6	3 (21.4)	1 (16.6)	82	7.9	29	5.8
	Fair	25.8	4 (28.6)	3 (50.0)	329	31.5	144	28.6
	Good	62.8	6 (42.9)	2 (33.3)	630	60.4	307	61.0
	Missing	5.8	1 (7.1)	0	2	0.2	23	4.6
No. Previous MIs	None	53.5	5 (35.7)	1 (16.6)	370	35.5	259	51.5
	One	42.6	3 (21.4)	5 (83.3)	311	29.8	214	42.5
	Two or more				59	5.7		
	Missing	3.9	6 (42.9)	0	303	29.1	30	6.0

Variable	Categories	NACS Database 2003 %	Deaths Phase I N (%)	Deaths Phase II N (%)	Phase I N	Phase I %	Phase II N	Phase II %
Dyspnoea Classification	NYHA 1	28.6	2 (14.3)	1 (16.6)	261	25.0	137	27.2
	NYHA 2	37.6	6 (42.9)	2 (33.3)	332	31.8	232	46.1
	NYHA 3				135	12.9		
	NYHA 4	24.6	2 (14.3)	3 (50.0)	13	1.2	107	21.3
	Missing	9.3	4 (28.6)	0	302	29.0	27	5.4
Angina Classification	CCS 0	17.0	1 (7.1)	1 (16.6)	38	3.6	66	13.1
	CCS 1				127	12.2		
	CCS 2	31.0	7 (50.0)	0	276	26.5	206	41.0
	CCS 3	47.3	1 (7.1)	5 (83.3)	237	22.7	204	40.6
	CCS 4				64	6.1		
	Missing	4.7	5 (35.7)	0	301	28.9	27	5.4
Peripheral Vascular Disease	No	86.2	10 (71.4)	5 (83.3)	886	84.9	416	82.7
	Yes	11.9	2 (14.3)	1 (16.6)	155	14.9	65	12.9
	Missing	1.9	2 (14.3)	0	2	0.2	22	4.4
Pulmonary Disease	None	*	9 (64.3)	4 (66.6)	919	88.1	405	80.5
	Asthma/COPD/emphysema		5 (35.7)	2 (33.3)	122	11.7	76	15.1
	Missing		0	0	2	0.2	22	4.4
Smoking History	Never smoked	*	5 (35.7)	2 (33.3)	184	17.6	127	25.2
	Ex-smoker		4 (28.6)	4 (66.6)	493	47.3	294	58.4
	Current smoker		0	0	58	5.6	55	10.9
	Missing		5 (35.7)	0	308	29.5	27	5.4
Left Main Stem Disease	No	67.9	10 (71.4)	2 (33.3)	479	45.9	324	64.4
	Yes	19.2	0	3 (50.0)	215	20.6	151	30.0
	Missing	12.9	4 (28.6)	1 (16.6)	349	33.5	28	5.6
No. Vessels Bypassed	1	4.0	0	1 (16.6)	32	3.1	20	4.0
	2	20.0	3 (21.4)	2 (33.3)	189	18.1	88	17.5
	3	49.0	7 (50.0)	1 (16.6)	507	48.6	228	45.3
	4	23.0	3 (21.4)	2 (33.3)	277	26.5	125	24.9
	5 or more	4.0	0	0	18	1.7	17	3.4
	Missing	0	1 (7.1)	0	20	1.9	25	5.0

Variable	Categories	NACS Database 2003 %	Deaths Phase I N (%)	Deaths Phase II N (%)	Phase I N	Phase I %	Phase II N	Phase II %
Parsonnet Score from Hard Data	1%	42.0	1 (7.1)	2 (33.3)	288	27.6	149	29.6
	5%	27.0	1 (7.1)	0	281	26.9	128	25.4
	9%	18.0	3 (21.4)	1 (16.6)	220	21.1	84	16.7
	17%	9.0	3 (21.4)	1 (16.6)	168	16.1	70	13.9
	31%	4.0	4 (28.6)	2 (33.3)	83	8.0	44	8.7
	Missing	50.0	2 (14.3)	0	3	0.3	28	5.6
Parsonnet Category with Catastrophic States and Other Rare Circumstances	1%	*	1 (7.1)	2 (33.3)	289	27.7	149	29.6
	5%		1 (7.1)	0	283	27.1	128	25.4
	9%		3 (21.4)	1 (16.6)	219	21.0	84	16.7
	17%		2 (14.3)	1 (16.6)	167	16.0	70	13.9
	31%		5 (35.7)	2 (33.3)	82	7.9	44	8.7
	Missing		2 (14.3)	0	3	0.3	28	5.6
EuroSCORE	Low risk	60.0	1 (7.1)	0	315	30.2	189	37.6
	Moderate risk	40.0	7 (50.0)	2 (33.3)	462	44.3	174	34.6
	High risk		5 (35.7)	4 (66.6)	247	23.7	110	21.9
	Missing	30.0	1 (7.1)	0	19	1.8	30	6.0
Urgency of Surgery	Elective	72.1	8 (57.1)	3 (50.0)	756	72.5	319	63.4
	Non Elective	27.3	5 (35.7)	3 (50.0)	285	27.3	183	36.4
	Missing	0.6	1 (7.1)	0	2	0.2	1	0.2
Time on the Waiting List (months)	0-3	*	8 (57.1)	4 (66.6)	636	61.0	324	64.4
	>3		2 (14.3)	0	84	8.1	3	0.6
	Not on list		3 (21.4)	2 (33.3)	305	29.4	176	35.0
	Missing		1 (7.1)	0	18	1.7	0	0
Preoperative Length of Stay	0-1 days	*	10 (71.4)	4 (66.6)	707	67.8	356	70.8
	2-7 days		3 (21.4)	1 (16.6)	193	18.5	95	18.9
	More than 1 week		1 (7.1)	1 (16.6)	143	13.7	52	10.3
CPB	No	17.0	1 (7.1)	1 (16.6)	132	12.7	54	10.7
	Yes	83.0	7 (50.0)	5 (83.3)	824	79.0	421	83.7
	Missing	0	6 (42.9)	0	87	8.3	28	5.6
Hospital	1	NA	10 (71.4)	3 (50.0)	581	55.7	283	56.3
	2		4 (28.6)	3 (50.0)	462	44.3	220	43.7

Variable	Categories	NACS Database 2003 %	Deaths Phase I N (%)	Deaths Phase II N (%)	Phase I N	Phase I %	Phase II N	Phase II %
Consultant Surgeon	A		0	2 (33.3)	126	12.1	71	14.1
	B		2 (14.3)	0	85	8.1	24	4.8
	C		3 (21.4)	1 (16.6)	86	8.2	41	8.2
	D		5 (35.7)	0	185	17.7	58	11.5
	E		0	1 (16.6)	117	11.2	36	7.2
	F	NA	0	X	5	0.5	X	X
	G		0	1 (16.6)	57	5.5	23	4.6
	H		1 (7.1)	0	74	7.1	33	6.6
	I		1 (7.1)	1 (16.6)	39	3.7	25	5.0
	J		1 (7.1)	0	122	11.7	X	X
	K		1 (7.1)	0	147	14.1	56	11.1
Day of the week on which the 5th postoperative day occurred.	Sunday				252	24.2	109	21.7
	Monday				187	17.9	106	21.1
	Tuesday				227	21.8	104	20.7
	Wednesday	NA			169	16.2	99	19.7
	Thursday				1	0.10	2	0.4
	Friday				4	0.40		
	Saturday				203	19.5	83	16.5

*Data not published

6.2 UNIVARIATE ANALYSES

This section presents the results of the univariate analyses and is divided into the following subsections; demographic, co-morbidities, illness severity, and preoperative and operative variables At the end of each subsection, a table summarises the variables that were independently associated with PLOS as a continuous variable (hypothesis 1) and PLOS within five days (hypothesis 2).

6.2.1 DEMOGRAPHIC VARIABLES

AGE

The mean age of the sample was 66.7 years (s.d. 9.3). Age was not normally distributed (K-S Z = 2.27, $p < 0.001$), and PLOS was not normally distributed for any age category; for patients less than 51 years (K-S Z = 2.59, $p < 0.001$), 51-60 years (K-S Z = 5.87, $p < 0.001$), 61-70 years (K-S Z = 5.48, $p < 0.001$), and over 71 years (K-S Z = 5.74, $p < 0.001$).

Table 6.2.1.1 shows the descriptive statistics for PLOS by age category.

TABLE 6.2.1.1:
POSTOPERATIVE LENGTH OF STAY BY AGE CATEGORY

Age Category (Years)	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤5days n (%)	>5 days n (%)
< 51	58	4	28	6.62 (3.79)	6 (5-7)	5	26 (44.8)	32 (55.2)
51-60	206	4	242	8.06 (17.56)	5 (5-7)	5	112 (54.4)	94 (45.6)
61-70	369	3	95	7.79 (6.62)	6 (5-8)	5	154 (41.7)	215 (58.3)
>70	410	4	92	8.87 (7.82)	7 (5-9)	5	125 (30.5)	285 (69.5)

Hypothesis 1

There was a small significant association between age in years and PLOS (r_s = 0.24; n = 941; $p < 0.001$). There were also significant differences among the four age categories and PLOS (K-W $\chi^2 = 49.63$; df = 3; $p < 0.001$).

The level of significance was adjusted to $p = 0.0083$ for post hoc comparisons which showed that PLOS was significantly longer for patients over 70 years old than patients less than 51 years old (M-W Z = -3.76, $p < 0.001$), 51-60 years (M-W Z = -6.53, $p < 0.001$), and 61-70 years (M-W Z = -3.57, $p < 0.001$). Patients 61-70 years had a significantly longer PLOS than patients 51-60 years (M-W Z = -3.56, $p < 0.001$). However, PLOS for patients less than 51 years did not differ from patients 51-60 years (M-W Z = -0.55, $p = 0.585$) or 61-70 years (M-W Z = -1.82, $p = 0.068$).

Figure 6.2.1.1 illustrates the median PLOS for patients in each of the four age categories.

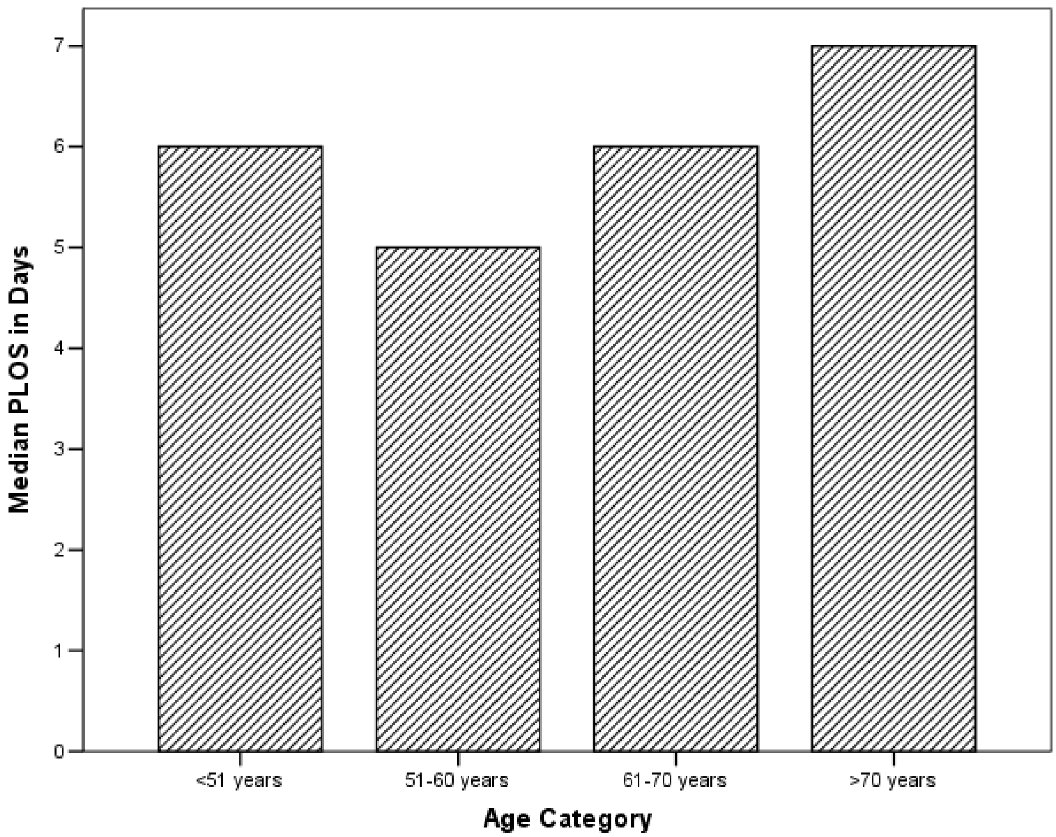


FIGURE 6.2.1.1:

The median postoperative length of stay for patients in each age category

Hypothesis 2

The mean ages of patients discharged within and after five days of surgery were 64.7 years (sd 9.1 years) and 68 years (sd 9.2 years) respectively. Age was not normally distributed for either those discharged within five days (K-S Z = 1.62, $p = 0.011$), or those discharged after five days (K-S Z = 2.31, $p < 0.001$).

There was a significant difference in the ages of patients discharged within five days and those who had a longer PLOS (M-W Z = -6.02, $p < 0.001$). There was also a significant association between age category and discharge within five days of surgery ($\chi^2 = 34.21$; df = 3; $p < 0.001$) but the magnitude of difference between the groups was low ($\tau = 0.18$; $p < 0.001$). Figure 6.2.1.2 illustrates the association between age category and discharge within five days.

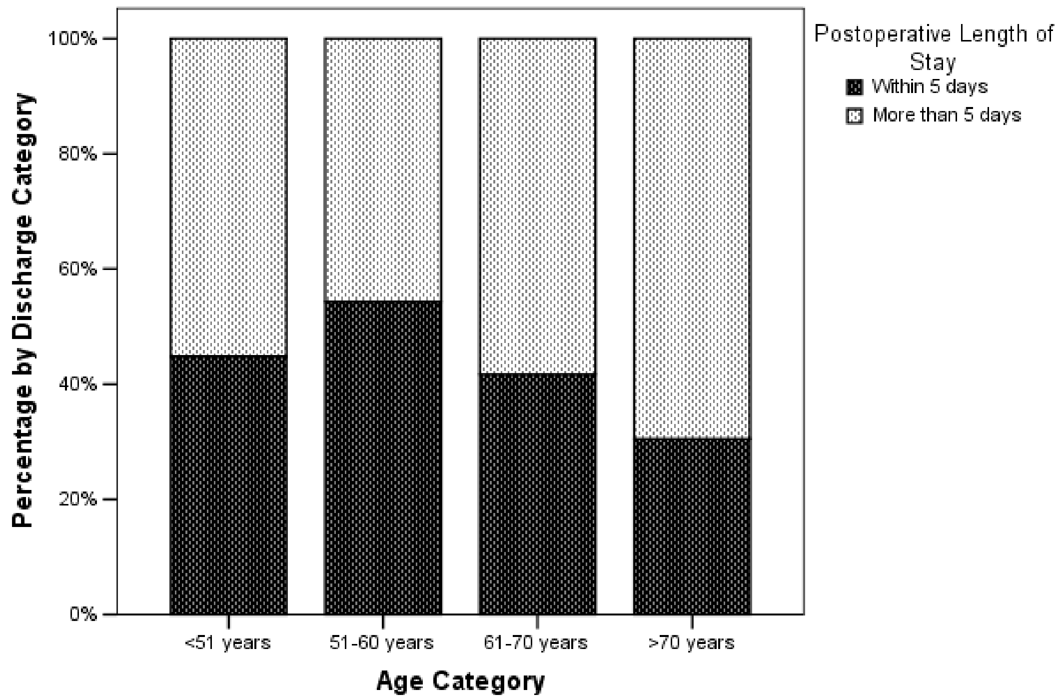


FIGURE 6.2.1.2:

The percentage of patients, in each age category, in each of the discharge groups

GENDER

The mean PLOS for men and women was 8.24 days and 8.05 days respectively. PLOS was not normally distributed for either men (K-S Z = 10.09, $p < 0.001$) or women (K-S Z = 3.42, $p < 0.001$).

Table 6.2.1.2 shows the descriptive statistics for gender and PLOS.

TABLE 6.2.1.2:
POSTOPERATIVE LENGTH OF STAY BY GENDER

Gender	N	PLOS							
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Male	838	3	242	8.24 (10.97)	6 (5-8)	5	351 (41.9)	487 (58.1)
Female	205	4	35	8.05 (4.83)	6 (5-9)	5	66 (32.2)	139 (67.8)

Hypothesis 1

Female gender was significantly associated with longer PLOS (M-W Z = -2.61, p = 0.009).

Hypothesis 2

There was a significant association between gender and discharge within five days ($\chi^2 = 6.45$; df = 1; p = 0.011) but the strength of the relationship was low ($\varphi = 0.08$, p = 0.011).

Figure 6.2.1.3 illustrates the association between gender and discharge type.

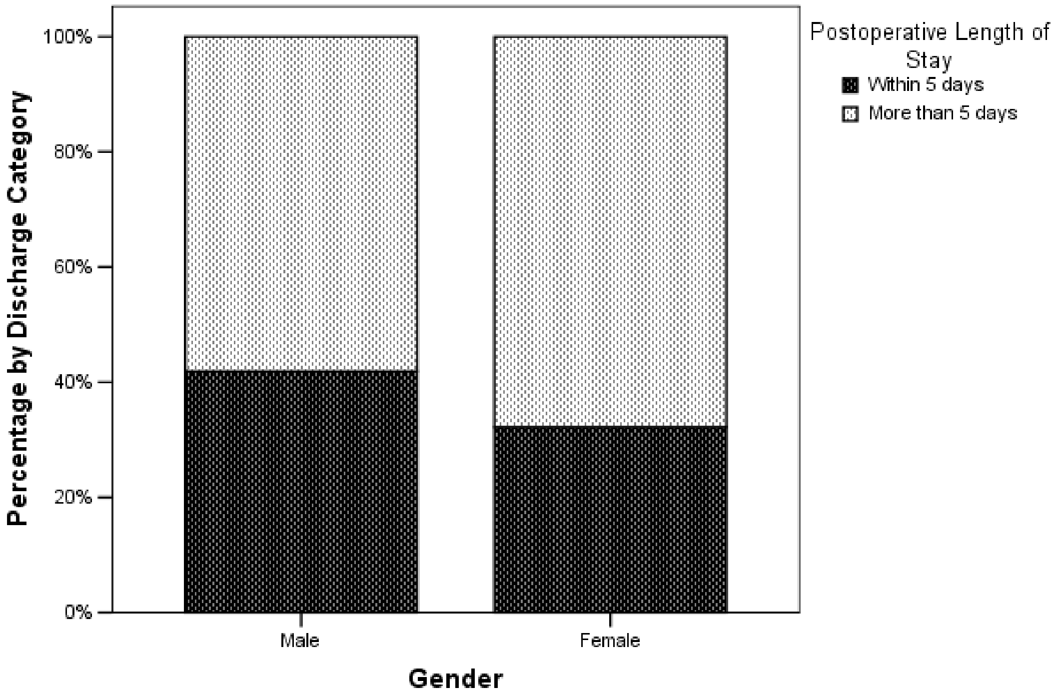


FIGURE 6.2.1.3:

The percentage of men and women in each of the discharge groups

BODY SURFACE AREA

BSA was not recorded for two patients (0.2%). BSA for the sample had a mean value of 1.90m^2 (sd 0.19m^2) and was normally distributed (K-S Z = 0.92, p = 0.372). Only eight patients had a BSA over 2.39m^2 so data for these patients was combined with that of patients with a BSA of 1.90-2.39m^2 and recoded as (3). PLOS was not normally distributed for patients with a BSA less than 1.70m^2 (K-S Z = 2.85, $p < 0.001$), 170-1.89m^2 (K-S Z = 7.05, $p < 0.001$), and 1.90m^2 or over (K-S Z = 6.64, $p < 0.001$).

Table 6.2.1.3 shows the descriptive statistics for the BSA classifications and

PLOS.

TABLE 6.2.1.3:
POSTOPERATIVE LENGTH OF STAY BY BODY SURFACE AREA CLASSIFICATION

BSA	**N**	**PLOS**						
		Min	**Max.**	**Mean (s.d)**	**Median (IQR)**	**Mode**	**≤ 5 days n (%)**	**> 5 days n (%)**
<1.70m^2	138	4	35	8.38 (5.27)	7 (5-9)	5	39 (28.3)	99 (71.7)
1.70-1.89m^2	359	4	242	8.86 (14.90)	6 (5-8)	5	142 (39.6)	217 (60.4)
≥1.90m^2	544	3	81	7.73 (6.36)	6 (5-8)	5	235 (43.2)	309 (56.8)
Missing	2						1	1

Hypothesis 1

There was a significant but weak association between BSA and PLOS (r_s = -0.06; n = 939; p = 0.050). There were also significant differences between the three BSA categories and PLOS (K-W χ^2 = 9.73; df = 2; p = 0.008) with the smallest patients having significantly longer PLOS than the largest patients.

The level of significance was adjusted to p = 0.016 for the following post hoc comparisons. Patients with a BSA less than 1.70m^2 did not differ significantly in PLOS from those with a BSA 1.70-1.89m^2 (M-W Z = -2.26, p = 0.024) but did differ from patients with a BSA greater than or equal to 1.90m^2 (M-W Z = -3.12, p = 0.002). Those with a BSA 1.70-1.89m^2 did not differ in PLOS from patients with a BSA greater than or equal to 1.90m^2 (M-W Z = -1.02, p = 0.310).

Figure 6.2.1.4 illustrates the median PLOS for each of the BSA categories.

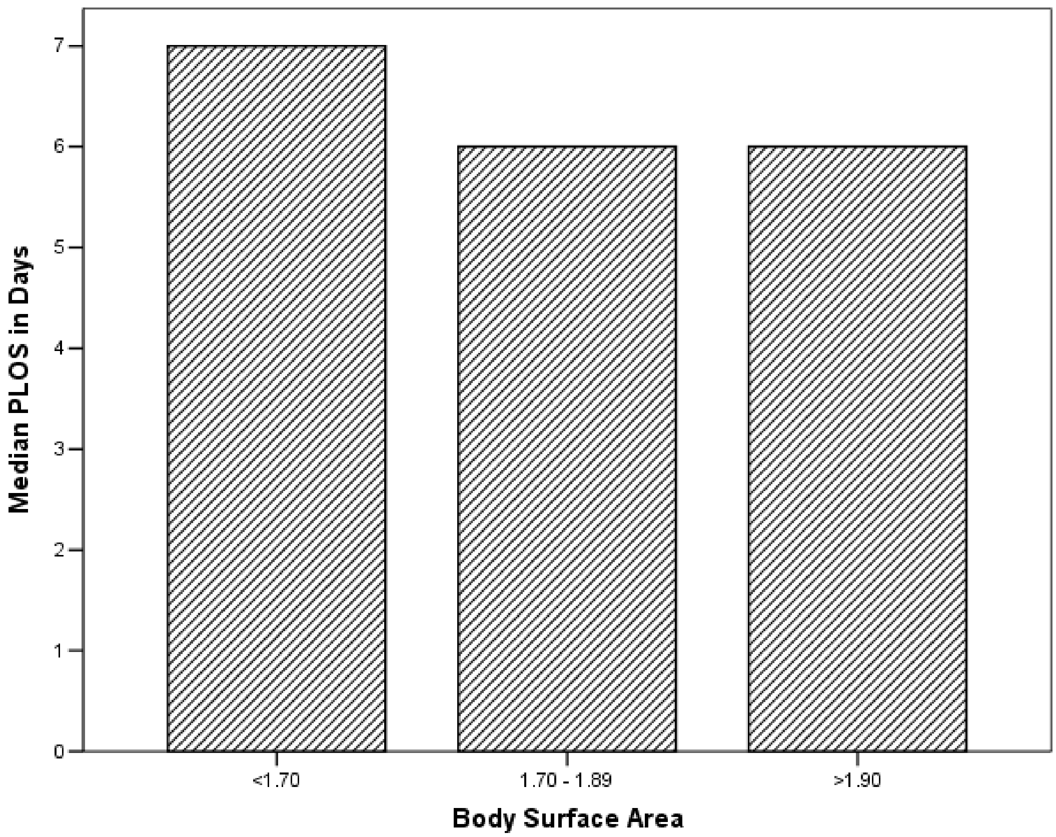


FIGURE 6.2.1.4:

The median postoperative length of stay for patients in each of the body surface area categories

Hypothesis 2

The mean BSA of patients discharged within and after five days of surgery was 1.92m^2 (s.d. 0.17m^2) and 1.89m^2 (s.d. 0.20m^2) respectively. BSA was normally distributed for both those discharged within five days (K-S Z = 0.88, p = 0.419) and those discharged after five days (K-S Z = 0.84, p = 0.488). A parametric test was therefore selected to test for differences in the BSA of those discharged within and after five days.

There was a significant difference in the BSA of those discharged within five days and those who had a longer PLOS (t = 2.84; df = 1039, p = 0.005). There was also a significant association between BSA category and discharge within five days of surgery ($\chi^2 = 10.28$; df = 2; p = 0.006) with a greater proportion of larger patients discharged within five days. However, the magnitude of difference between the groups was low (τ = -0.09; p = 0.004).

Figure 6.2.1.5 illustrates the association between BSA category and discharge within five days.

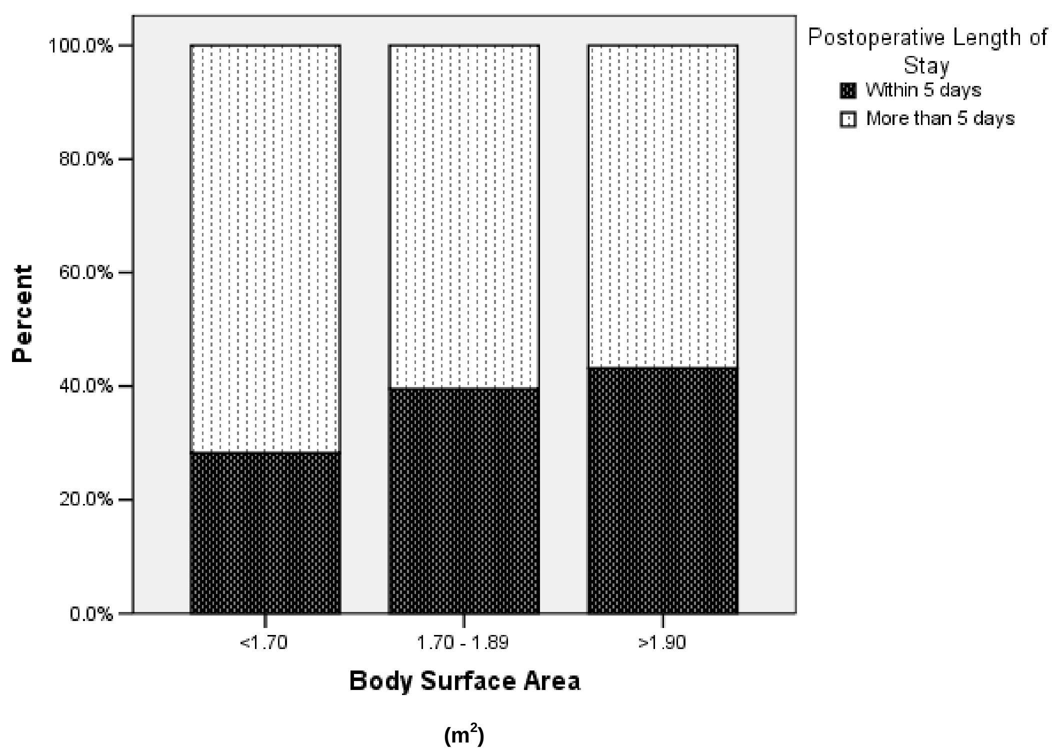


FIGURE 6.2.1.5:

The percentage of patients in each of the discharge groups by body surface area category

BODY MASS INDEX

BMI was not recorded for two patients (0.2%). BMI had a mean value of 28.10 (sd 9.71) and was not normally distributed (K-S Z = 6.77, $p < 0.001$). Due to the small number of patients classified as underweight this group was combined with the normal weight group and recoded as (1). Similarly, severely obese patients were combined with obese patients and recoded as (3). PLOS was not normally distributed for patients with a BMI less than 25 (K-S Z = 6.38, $p < 0.001$), 25.00-30.00 (K-S Z = 6.56, $p < 0.001$), or greater than 30.00 (K-S Z = 4.51, $p < 0.001$).

Table 6.2.1.4 shows the descriptive statistics for PLOS by BMI classification.

TABLE 6.2.1.4:
POSTOPERATIVE LENGTH OF STAY BY BODY MASS INDEX CLASSIFICATION

BMI Category (kg/m^2)	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
<25.00	296	4	242	9.09 (15.42)	6 (5-9)	5	112 (37.8)	184 (62.2)
25.0-30.0	476	4	92	7.46 (6.41)	6 (5-8)	5	200 (42.0)	276 (58.0)
>30.00	269	3	81	8.55 (7.58)	6 (5-9)	5	104 (38.7)	165 (61.3)
Missing	2						1	1

Hypothesis 1

There was no significant association between BMI and PLOS ($r_s = -0.14$; n = 939; p = 0.669), but there were significant differences between BMI category and PLOS (K-W $\chi^2 = 6.14$; df = 2; p = 0.047). However, none of the post hoc comparisons were significant at the adjusted level of p = 0.016. Those with a BMI less than 25.00 did not differ significantly in PLOS from those with a BMI 25.00-30.00 (M-W Z = -2.07, p = 0.039) or those with a BMI over 30.00 (M-W Z = -0.05, p = 0.964). Patients with a BMI of 25.00-30.00 did not differ in PLOS from those with a BMI over 30.00 (M-W Z = -2.04, p = 0.042).

Hypothesis 2

The mean BMI of patients discharged within and after five days of surgery was 28.35 (sd 11.81) and 27.94 (sd 8.01) respectively. The BMI was not normally distributed for either those discharged within five days (K-S Z = 5.26, $p < 0.001$), or those discharged after five days (K-S Z = 4.23, $p < 0.001$).

There was no significant difference in the BMI's of those discharged within five days and those who had a longer PLOS (M-W Z = -0.79, p = 0.430). Similarly, there was no significant association between BMI category and discharge within five days of surgery (χ^2 = 1.58; df = 2; p = 0.453).

MARITAL STATUS

Marital status was not stated for 81 patients (7.8%). Due to the small number of patients who were cohabiting or separated, these groups were combined with married and divorced patients and recoded as (1) and (2) respectively. PLOS was not normally distributed for patients who were single (K-S Z = 2.48, $p < 0.001$), married/cohabiting (K-S Z = 7.86, $p < 0.001$), widowed (K-S Z = 3.15, $p < 0.001$), or divorced/separated (K-S Z = 2.20, $p < 0.001$).

Table 6.2.1.5 shows the descriptive statistics for marital status and PLOS.

TABLE 6.2.1.5:
POSTOPERATIVE LENGTH OF STAY BY MARITAL STATUS

Marital Status	N	PLOS						
		Min	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Married/Cohabiting	736	4	55	7.75 (6.70)	6 (5-8)	5	319(43.3)	417(56.7)
Separated/Divorced	71	4	44	7.75 (5.34)	6 (5-8)	5	27 (38.2)	44 (62.0)
Single	52	4	43	8.67 (7.45)	6 (6-10)	6	17 (36.7)	35 (67.3)
Widowed	103	4	92	9.78 (10.21)	7 (5-8)	6	23 (22.3)	80 (77.7)
Missing	81						31 (38.3)	50 (61.7)

Hypothesis 1

There were significant differences in PLOS by marital status (K-W $\chi^2 = 19.72$; df = 3; $p < 0.001$). The level of significance was adjusted to $p = 0.008$ for post hoc comparisons.

Single patients did not differ significantly in PLOS from patients who were married/co-habiting (M-W Z = -0.62, p = 0.536), or separated/divorced (M-W Z = -2.07, p = 0.790), or widowed (M-W Z = -2.06, p = 0.039). Married/co-habiting patients had significantly shorter PLOS than patients who were widowed (M-W Z = -4.40, p < 0.001), but did not differ in PLOS from separated/divorced (M-W Z = -1.11, p = 0.269). Patients who were separated/divorced did not differ in PLOS from patients who were widowed (M-W Z = -2.13, p = 0.033).

Figure 6.2.1.6 illustrates the median PLOS by marital status.

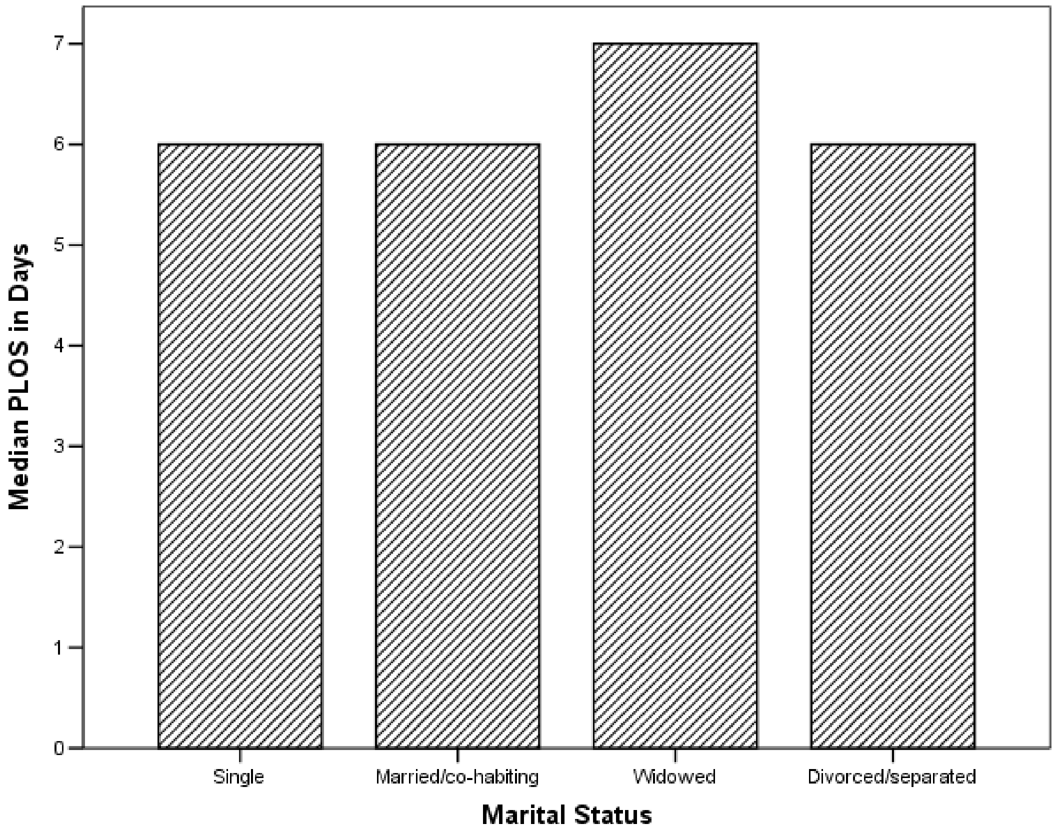


FIGURE 6.2.1.6:

The median postoperative length of stay by marital status

Hypothesis 2

There was a significant association between marital status and discharge within five days ($\chi^2 = 18.07$; df = 3; $p < 0.001$) but the strength of the relationship was low (Cramér's V = 0.14; $p < 0.001$).

Figure 6.2.1.7 illustrates the relationship between marital status and discharge within five days.

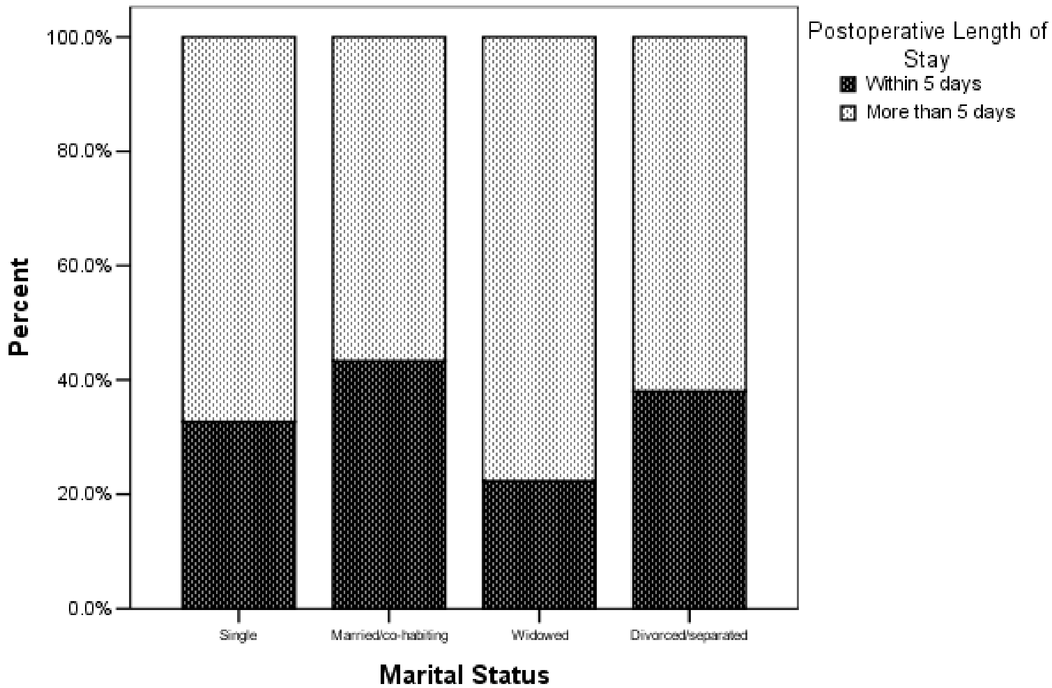


FIGURE 6.2.1.7:

The percentage of patients in each of the discharge groups by marital status

LIVING ALONE

Living arrangements were not detailed for 112 patients (10.7%). PLOS was not normally distributed for either those who lived alone (K-S Z = 2.99, $p < 0.001$), or those who did not live alone (K-S Z = 7.10, $p < 0.001$).

Table 6.2.1.6 shows the descriptive statistics for living alone and PLOS.

TABLE 6.2.1.6:
POSTOPERATIVE LENGTH OF STAY BY WHETHER A PATIENT LIVED ALONE

Living Alone	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
No	798	4	95	7.85 (6.68)	6 (5-8)	5	335 (42.0)	463 (58.0)
Yes	133	4	45	8.32 (5.98)	6 (5-9)	6	36 (27.1)	97 (72.9)
Missing	112						46	66

Hypothesis 1

Patients who lived alone had a significantly longer PLOS than patients who did not live alone (M-W Z = -2.58, p = 0.010).

Hypothesis 2

There was a significant association between living arrangements and discharge within five days (χ^2 = 10.58; df = 1; p = 0.001) but the strength of the relationship was low (φ = 0.11; p = 0.001).

Figure 6.2.1.8 illustrates the relationship between living alone and discharge within five days.

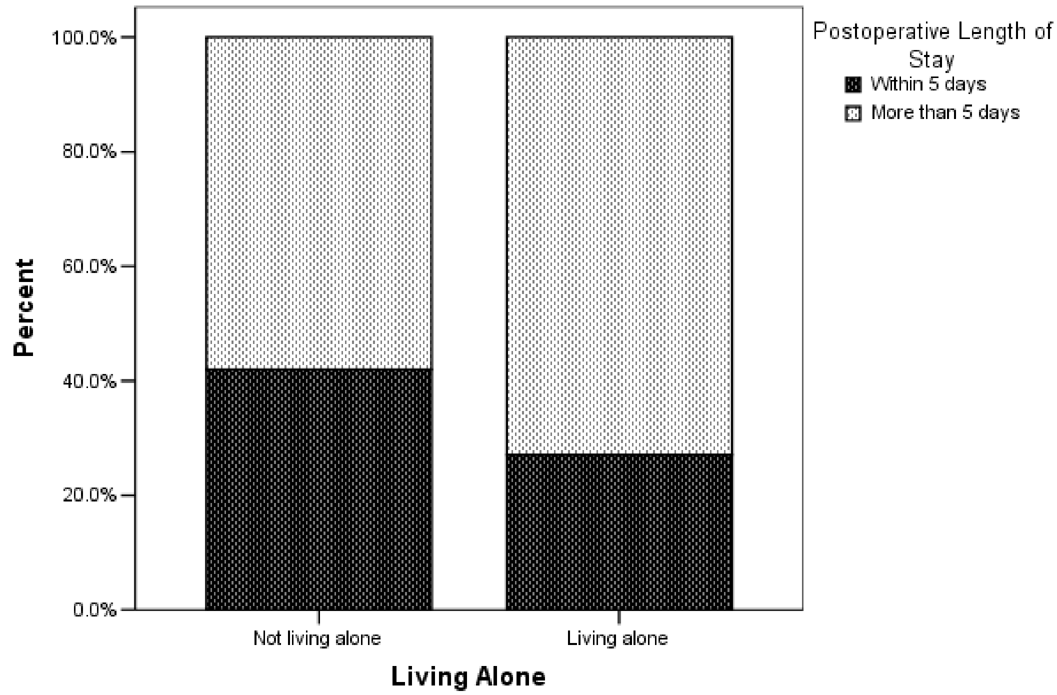


FIGURE 6.2.1.8:

The percentage of patients in each of the discharge groups by whether a patient was living alone

EMPLOYMENT STATUS

Employment status was not stated for 525 patients (50.3%). PLOS was not normally distributed according to employment status; employed/self-employed (K-S Z = 3.44, $p < 0.001$), retired/unemployed/not working (K-S Z = 6.89, $p < 0.001$).

Table 6.2.1.7 shows the descriptive statistics for employment and PLOS.

TABLE 6.2.1.7:
POSTOPERATIVE LENGTH OF STAY BY EMPLOYMENT

Employment	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Employed/ Self-employ.	144	4	31	7.10 (4.56)	6 (5-7)	5	71 (49.3)	73 (50.7)
Retired/ Unemploy.	374	4	242	9.47 (14.87)	6 (5-9)	5	122 (32.6)	252 (67.4)
Missing	525						224	301

Hypothesis 1

Patients who were working had significantly shorter PLOS than patients who were not working (M-W Z = -3.81, $p < 0.001$).

Hypothesis 2

There was a significant association between employment status and discharge within five days ($\chi^2 = 12.38$; df = 1; $p < 0.001$) but the strength of the relationship was low ($\varphi = 0.16$; $p < 0.001$).

Figure 6.2.1.9 illustrates the relationship between employment status and discharge within five days.

FIGURE 6.2.1.9:

The percentage of patients in each of the discharge groups by employment

DEPRIVATION INDEX

The Index of Multiple Deprivation (IMD) was not calculated for 39 patients (3.6%) as the postcodes recorded were not recognised. The mean IMD value was 22.04 (sd 14.19), ranged from 1.62 to 65.35, and was not normally distributed (K-S Z = 3.00, $p < 0.001$). PLOS was not normally distributed for any of the IMD quartiles; first (K-S Z = 4.40, $p < 0.001$), second (K-S Z = 5.17, $p < 0.001$), third (K-S Z = 6.07, $p < 0.001$), and fourth (K-S Z = 4.73, $p < 0.001$).

Table 6.2.1.8 shows the descriptive statistics for the IMD and PLOS.

TABLE 6.2.1.8:
POSTOPERATIVE LENGTH OF STAY BY THE INDEX OF MULTIPLE DEPRIVATION

IMD 2004 Quartiles (range)	N	PLOS						
		Min.	Max	Mean PLOS (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
1st (1.62-10.46)	252	4	5	7.73 (6.21)	6 (5-8)	5	110 (43.6)	142 (56.3)
2nd (10.47-19.10)	252	4	81	7.79 (7.22)	6 (5-7.75)	5	112 (44.4)	140 (55.6)
3rd (19.16-31.14)	250	3	242	8.43 (15.53)	6 (5-8)	5	101 (40.4)	149 (60.0)
4th (31.48-65.35)	251	4	95	8.93 (9.33)	7 (5-9)	5	80 (31.9)	171 (68.1)
Missing	38						14	24

Hypothesis 1

There was a significant but weak association between IMD and PLOS ($r_s = 0.09$; $n = 908$; $p = 0.006$). There were also significant differences among the quartiles of the IMD and PLOS (K-W $\chi^2 = 13.21$; df = 3; $p < 0.004$).

The level of significance was adjusted to $p = 0.008$ for the following post hoc comparisons. Patients living in the least deprived areas did not differ in PLOS from patients in the second quartile (M-W Z = -0.47, p = 0.637), or the third quartile (M-W Z = -0.77, p = 0.444), but had significantly shorter PLOS than patients in the most deprived areas (M-W Z = -2.84, p = 0.005). Patients in the second quartile of the IMD did not differ in PLOS from patients in the third quartile (M-W Z = -1.28, p = 0.202), but did have significantly shorter PLOS than patients in the fourth quartile (M-W Z = -3.36, p = 0.001). Patients in the third quartile of the IMD did not differ significantly in PLOS to patients in the most deprived areas (M-W Z = -2.11, p = 0.035).

Figure 6.2.1.10 illustrates the median PLOS by quartile of the IMD 2004.

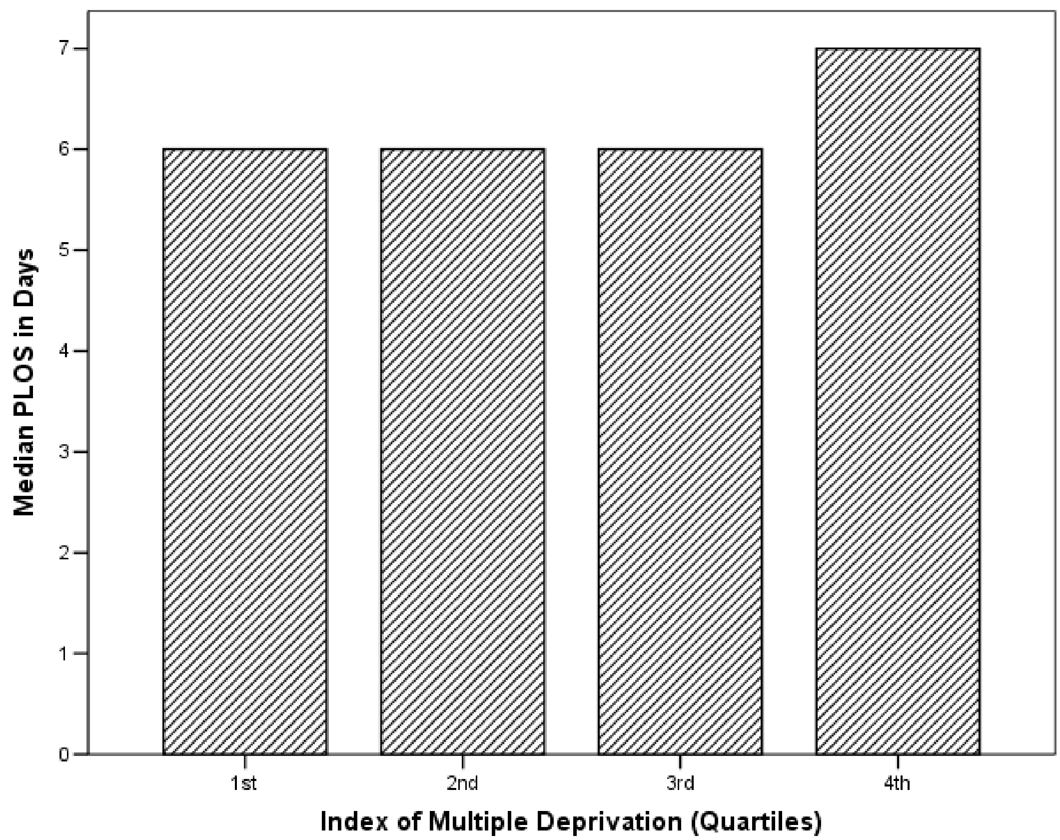


FIGURE 6.2.1.10:

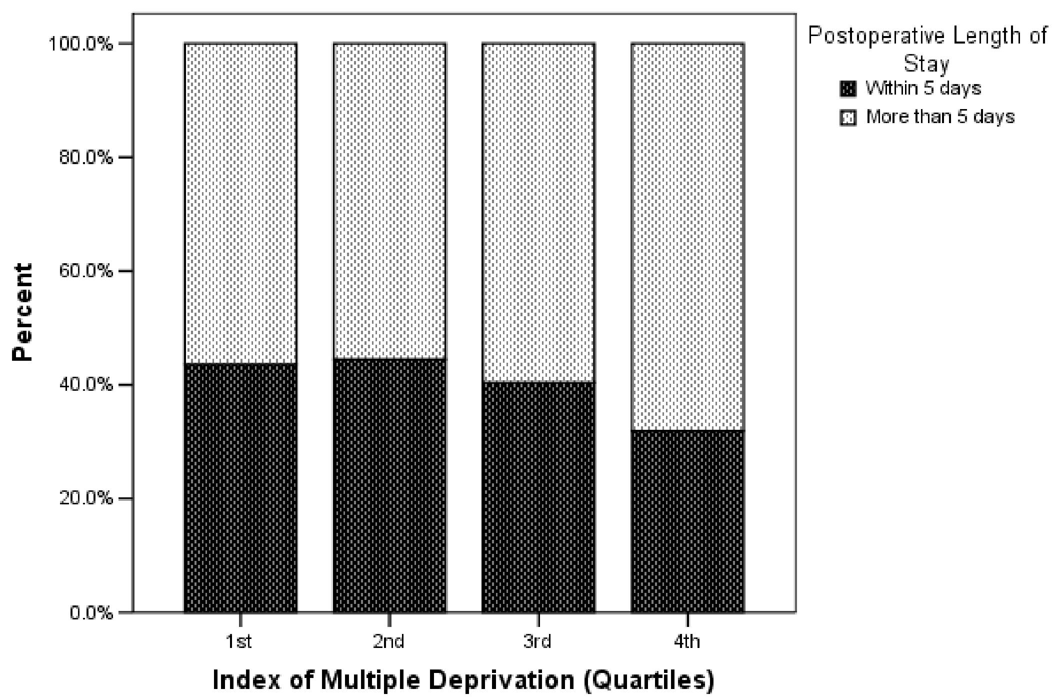
The median postoperative length of stay by index of multiple deprivation quartiles

Hypothesis 2

The mean IMD of patients discharged within and after five days of surgery were 20.34 (sd 12.93) and 23.18 (sd 14.88) respectively. The IMD's were not normally distributed for either those discharged within five days (K-S Z = 2.17, $p < 0.001$), or those discharged after five days (K-S Z = 2.27, $p < 0.001$).

Patients discharged within five days had significantly lower IMD's than those who had a longer PLOS (M-W Z = -2.65; p = 0.008). There was also a significant association between IMD quartile and discharge within five days of surgery (χ^2 = 10.39; df = 3; p = 0.016). However, the strength of the association was low (τ = 0.10; p = 0.004).

Figure 6.2.1.11 illustrates the relationship between IMD quartile and discharge within five days.



<u>FIGURE 6.2.1.11:</u>

<u>The percentage of patients in each of the discharge groups by index of multiple deprivation quartiles.</u>

ETHNIC GROUP

The ethnic group was not stated for 148 patients (14.2%). Due to the small number of patients in some of the non-white groups, these patients were collectively grouped as non-white for the analysis and recoded as (2). PLOS was not normally distributed for the white ethnic group (K-S Z = 7.74, p < 0.001), or the non-white ethnic group (K-S Z = 5.01, p < 0.001).

Table 6.2.1.9 shows the descriptive statistics for each ethnic group and PLOS.

TABLE 6.2.1.9:
POSTOPERATIVE LENGTH OF STAY BY ETHNIC GROUP

Ethnic Group	N	PLOS						
		Min.	Max.	Mean (sd)	Median (IQR)	Mode	≤5 days n	>5 days n
White	731	4	92	7.99 (6.99)	6 (5-8)	5	296	435
Mixed	6	5	28	9.33 (9.18)	5.5 (5-12.25)	5	3	3
Asian or Asian British	136	4	95	8.07 (8.46)	6 (5-8)	5	48	88
Black or Black British	13	5	14	7.77 (2.77)	7 (5.5-9)	5	3	10
Chinese or Other	9	4	242	33.8 (78.11)	8 (6-12.5)	6	1	8
Non-white	164	4	242	9.51 (19.91)	6 (5-8)	5	55	109
Unknown	148						66	82

Hypothesis 1

There were no significant differences in PLOS between the groups (M-W Z = -1.09; p = 0.276).

Hypothesis 2

There was no significant association between ethnic group and discharge within five days of surgery (χ^2 = 2.72; df = 1; p = 0.099).

Tables 6.2.1.10 and 6.2.1.11 illustrate the mean and standard deviation of each continuous variable by ethnic group, and each categorical variable by ethnic group, respectively. Whilst it was not possible to statistically analyse small and unequal groups meaningfully, these descriptive statistics suggest that white patients had the largest BMI, mixed patients were younger and spent the least time on the waiting list, Asian or Asian British patients had the lowest mortality risk scores, black or black British patients had the fewest number of vessels bypassed and the highest deprivation scores, whilst the Chinese or Other ethnic group had the highest Parsonnet scores.

TABLE 6.2.1.10:
MEAN (S.D) FOR EACH CONTINUOUS VARIABLE BY ETHNIC GROUP

Variable	**Ethnic Group**				
	White	**Mixed**	**Asian or Asian British**	**Black or Black British**	**Chinese or Other ethnic group**
Age (years)	66.9 (8.6)	57.0 (11.8)	63.5 (8.9)	68.3 (10.4)	72.0 (5.8)
BSA (m^{2})	1.9 (0.2)	1.8 (0.1)	1.8 (0.2)	1.8 (0.1)	1.8 (0.1)
BMI	29.0 (13.2)	25.0 (1.6)	26.7 (3.7)	24.6 (3.0)	25.1 (2.4)
No. Vessels Bypassed	3.0 (0.8)	NA	3.1 (0.8)	2.00 (0.8)	3.3 (0.5)
Parsonnet Score (Hard data)	9.0 (6.2)	9.0 (2.6)	7.6 (5.2)	9.7 (4.6)	12.0 (7.4)
EuroSCORE	3.4 (2.3)	4.0 (1.0)	2.7 (1.7)	3.7 (3.0)	3.9 (2.1)
IMD 2004	20.4 (13.6)	37.9 (13.4)	27.5 (14.1)	43.1 (11.0)	24.9 (18.1)

TABLE 6.2.1.11:
EACH CATEGORICAL VARIABLE BY ETHNIC GROUP (N)

Variable		Ethnic Group				
		White	Mixed	Asian or Asian British	Black or Black British	Chinese or Other ethnic group
Gender	Male	579	5	107	10	8
	Female	152	1	29	3	1
Diabetes	Not diabetic	561	2	60	7	4
	Diet-controlled	40	0	12	1	1
	Oral therapy	72	2	43	3	3
	Insulin	57	2	20	2	1
	Patient diabetic	169	4	75	6	5
Hypertension	No	142	0	24	2	0
	Yes	587	6	111	11	9
Renal Disease	No	705	5	132	10	9
	Yes	22	1	3	3	0
Ejection Fraction	Poor	53	2	10	1	1
	Fair	233	3	42	3	2
	Good	444	1	83	9	6
No. Previous MI's	None	273	2	44	6	3
	One	231	1	39	3	1
	Two or more	36	1	8	3	0
Dyspnoea Classification	NYHA 1	190	1	31	3	2
	NYHA 2	244	2	39	5	1
	NYHA 3 & 4	107	1	22	4	0
Angina Classification	CCS 0	27	0	5	0	0
	CCS 1	94	1	15	2	2
	CCS 2	212	1	29	4	1
	CCS 3	169	1	30	6	1
	CCS 4	39	1	13	0	0
Left Main Stem Disease	No	354	4	63	9	2
	Yes	151	0	26	2	1
Peripheral Vascular Disease	No	629	4	116	9	6
	Yes	101	2	19	4	3
Pulmonary Disease	None	655	6	114	10	8
	Asthma/COPD/emphysema	75	0	21	3	1
Smoking History	Never smoked	118	0	37	6	1
	Ex-smoker	377	3	46	4	3
	Current smoker	43	1	7	2	0
No. Vessels Bypassed	1 or 2	163	0	29	8	0
	3	357	4	57	5	6
	4 or 5	202	2	45	0	3
Cardiopulmonary Bypass	No	88	1	16	3	2
	Yes	604	4	98	9	7
Urgency of Surgery	Elective	554	4	93	10	7
	Non Elective	176	2	42	3	2
Time on the Waiting List (months)	0-3	471	4	77	7	6
	>3	57	0	14	0	2
	Not on list	187	2	44	5	1

Variable		Ethnic Group				
		White	Mixed	Asian or Asian British	Black or Black British	Chinese or Other ethnic group
Preoperative Length of Stay	**0-1 days**	514	3	91	7	7
	2-7 days	125	1	24	2	1
	More than 1 week	92	2	21	4	1
Hospital	**1**	383	3	81	4	4
	2	348	3	55	9	5
Consultant Surgeon	**A**	95	0	17	0	0
	B	68	0	4	0	2
	C	50	0	13	3	0
	D	133	2	30	8	3
	E	98	1	6	1	0
	F	4	0	0	0	0
	G	40	1	11	0	1
	H	59	0	8	0	0
	I	29	1	4	0	0
	J	67	1	18	0	2
	K	88	0	25	1	1
Day of the week on which the 5th postoperative day occurred.	**Sunday**	175	3	38	1	1
	Monday	144	1	19	1	2
	Tuesday	158	0	25	6	3
	Wednesday	109	1	22	0	2
	Thursday	1	0	0	0	0
	Friday	2	0	1	0	0
	Saturday	142	1	31	5	1
Marital Status	**Single**	42	0	3	3	1
	Married / Co-habiting	521	5	115	6	6
	Widowed	88	0	12	0	0
	Separated/Divorced	63	1	2	4	0
Living Alone	**No**	569	5	123	9	6
	Yes	121	0	2	3	1
Employment	**Retired**	257	2	44	6	4
	Working	103	1	22	1	1
	Not working	28	1	14	1	0

Table 6.2.1.12 summarises the univariate test results for the demographic variables.

TABLE 6.2.1.12:
SUMMARY OF UNIVARIATE TESTS RESULTS FOR DEMOGRAPHIC VARIABLES

Variable	Groups	N	% of total	PLOS ≤ 5 days (n)	PLOS > 5 days (n)	Association with PLOS	Association with PLOS ≤ 5 days
Age						r_s = 0.24, p < 0.001	M-W Z = -6.02, p < 0.001
Age Category (Years)	< 51 51-60 61-70 >70	58 206 369 410	5.6 19.8 35.4 39.3	26 112 154 125	32 94 215 285	K-W χ^2 = 49.63, df = 3; p < 0.001	χ^2 = 34.21, df = 3; p < 0.001 τ = 0.18; p < 0.001
Gender	Male Female	838 205	80.3 19.7	351 66	487 139	M-W Z = -2.61, p = 0.009	χ^2 = 6.45, df = 1; p = 0.011 φ = 0.08, p = 0.011
Body Surface Area (BSA)		1041				r_s = -0.06, p = 0.050	t = 2.84, p = 0.005
BSA Category	<1.70m^2 1.70-1.89m^2 ≥1.90m^2 Missing	138 359 544 2	13.2 34.4 52.2 0.2	39 142 235 1	99 217 309 1	K-W χ^2 = 9.73, df = 2; p = 0.008.	χ^2 = 10.28, df = 2; p = 0.006 τ = -0.09; p = 0.004
Body Mass Index (BMI)		1041				r_s = -0.14, p = 0.669	M-W Z = -0.79, p = 0.430
BMI Category	<25.0 25.0-30.0 >30.0 Missing	296 476 269 2	28.4 45.6 25.8 0.2	112 200 104 1	184 276 165 1	K-W χ^2 = 6.14, df = 2; p = 0.047	χ^2 = 1.58, df = 2; p = 0.453
Marital Status	Single Married/Co-habiting Widowed Separated/Divorced Missing	52 736 103 71 81	5.0 70.6 9.9 6.8 7.8	17 319 23 27 31	35 417 80 44 50	K-W χ^2 = 19.72, df = 3; p < 0.001	χ^2 = 18.07, df = 3; p < 0.001 Cramér's V = 0.14, p < 0.001
Living Alone	No Yes	798 133	76.5 12.8	335 36	463 97	M-W Z = -2.58, p = 0.010	χ^2 = 10.58, df = 1; p = 0.001

Variable	Groups	N	% of total	PLOS ≤ 5 days (n)	PLOS > 5 days (n)	Association with PLOS	Association with PLOS ≤ 5 days
	Missing	112	10.7	46	66		φ = 0.11; p = 0.001
Employment	Employed/self-employed Retired/unemployed Missing	144 374 525	13.8 35.9 50.3	71 122 224	73 252 301	M-W Z = -3.81, p < 0.001	χ^2 = 12.38, df = 1; p < 0.001 φ = 0.16, p < 0.001
Deprivation Index (ID 2004)		1005	96.4			r_s = 0.09, p = 0.006	M-W Z = -2.65, p = 0.008
ID 2004 Quartiles	1st 2nd 3rd 4th Missing	252 252 250 251 38	24.2 24.2 24.0 24.1 3.6	110 112 101 80 14	142 140 149 171 24	K-W χ^2 = 13.21, df = 3; p = 0.004	χ^2 = 10.39, df = 3; p = 0.016 τ = 0.10; p = 0.004
Ethnic Group	White Non-White Missing	731 164 148	70.1 15.7 14.2	296 55 66	435 109 82	M-W Z = -1.09, p = 0.276	χ^2 = 2.72, df = 1; p = 0.099

6.2.2 CO-MORBIDITY

DIABETES

Information on diabetes was not recorded for two patients (0.2%). PLOS was not normally distributed for any of the diabetic groups as follows: not diabetic (K-S Z = 7.64, $p < 0.001$), diabetic patients controlled by diet (K-S Z = 2.75, $p < 0.001$), oral therapy (K-S Z = 4.71, $p < 0.001$), diet or oral therapy (K-S Z = 5.52, $p < 0.001$), insulin therapy (K-S Z = 2.23, $p < 0.001$), or diabetic patients as a whole (K-S Z = 6.30, $p < 0.001$).

Table 6.2.2.1 shows the descriptive statistics for diabetes and PLOS.

TABLE 6.2.2.1:
POSTOPERATIVE LENGTH OF STAY BY DIABETES CLASSIFICATION

Diabetes	N	PLOS						
		Min.	Max.	Mean (s.d)	Median	Mode	≤ 5 days n (%)	> 5 days n (%)
Not diabetic	744	3	92	7.69 (6.28)	6 (5-8)	5	321 (43.1)	423 (56.9)
Diet-controlled	62	4	81	8.84 (10.45)	6 (5-8)	6	18 (29.0)	44 (71.0)
Oral therapy	139	4	242	9.47 (21.54)	6 (5-8)	5	54 (38.8)	85 (61.2)
Insulin	96	4	43	9.98 (7.13)	7 (6-11)	5	23 (24.0)	73 (76.0)
*Diet or oral therapy	201	4	242	9.27 (18.81)	6 (5-8)	5	72 (35.8)	129 (64.2)
*Patient diabetic	297	4	242	9.50 (15.98)	6 (5-9)	5	95 (32.0)	202 (68.0)
Missing	2						1	1

* Reclassification

Hypothesis 1

There were significant differences between the four classifications of diabetes and PLOS (K-W $\chi^2 = 23.33$; df = 3; $p < 0.001$). The level of significance was adjusted to $p = 0.0083$ for post hoc comparisons.

Non diabetic patients differed significantly in PLOS from diabetic patients controlled on insulin (M-W Z = -4.71, $p < 0.001$), but not by diet (M-W Z = -1.30, $p = 0.193$), or oral therapy (M-W Z = -0.42, $p = 0.675$). Diet-controlled diabetic patients did not differ in PLOS from patients treated with oral therapy (M-W Z = -0.98, $p = 0.330$), or insulin (M-W Z = -2.22, $p = 0.027$). Diabetic patients treated with oral therapy did differ in PLOS from patients treated with insulin (M-W Z = -3.64, $p < 0.001$).

Figure 6.2.2.1 illustrates the median length of stay for each of the four diabetic classifications.

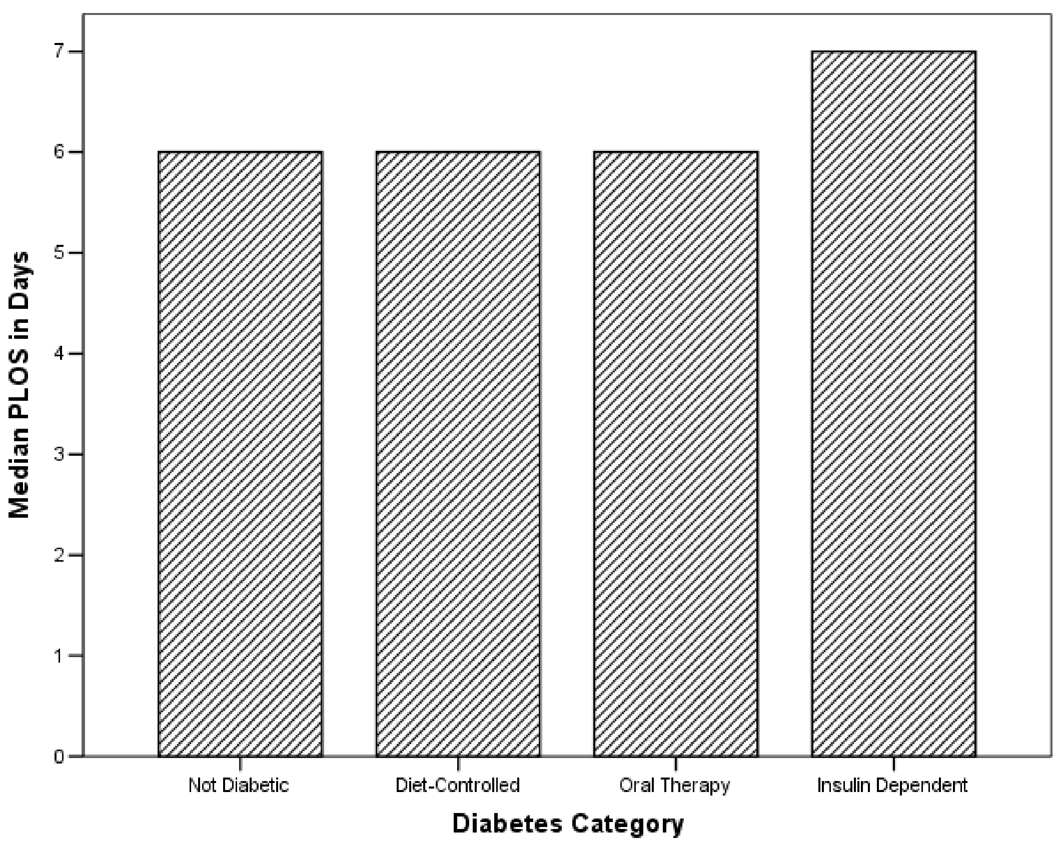


FIGURE 6.2.2.1:

The median postoperative length of stay for diabetic patients (4 classifications)

There were also significant differences between the three classifications of diabetes and PLOS (K-W χ^2 = 22.55; df = 2; p < 0.001). The level of significance was adjusted to p = 0.017 for post hoc comparisons.

Non diabetic patients differed significantly in PLOS from diabetic patients controlled on insulin (M-W Z = -4.71, p < 0.001), but not diet or oral therapy (M-W Z = -1.00, p = 0.316). Diabetic patients treated with diet or oral therapy did differ in PLOS from patients treated with insulin (M-W Z = -3.59, p < 0.001). Figure 6.2.2.2 illustrates the median length of stay for each of the three diabetic classifications.

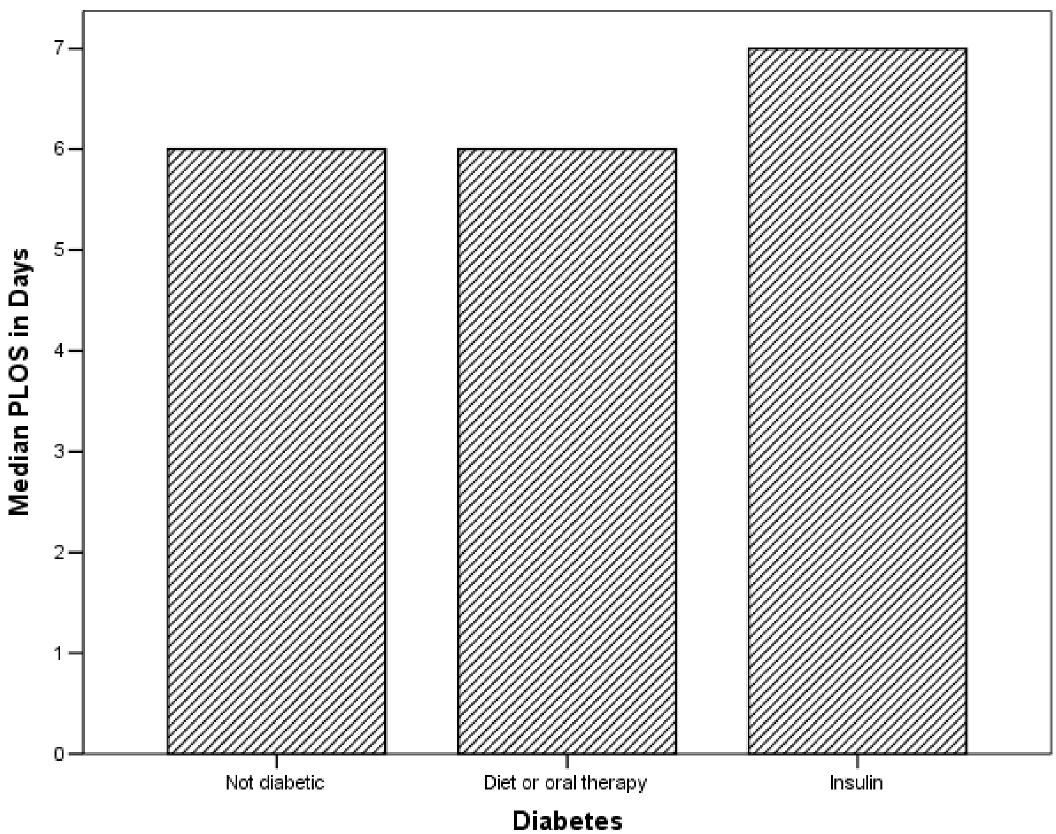


FIGURE 6.2.2.2:

The median postoperative length of stay for diabetic patients (3 classifications)

The presence of diabetes was observed to significantly increase PLOS (M-W Z = -3.19, p = 0.001).

Hypothesis 2

There was a significant association between the four diabetic groups and discharge within five days (χ^2 = 16.55; df = 3; p = 0.001) but the magnitude of difference was low (τ = 0.13; p = 0.001).

Figure 6.2.2.3 illustrates the association between the four diabetic groups and discharge within five days.

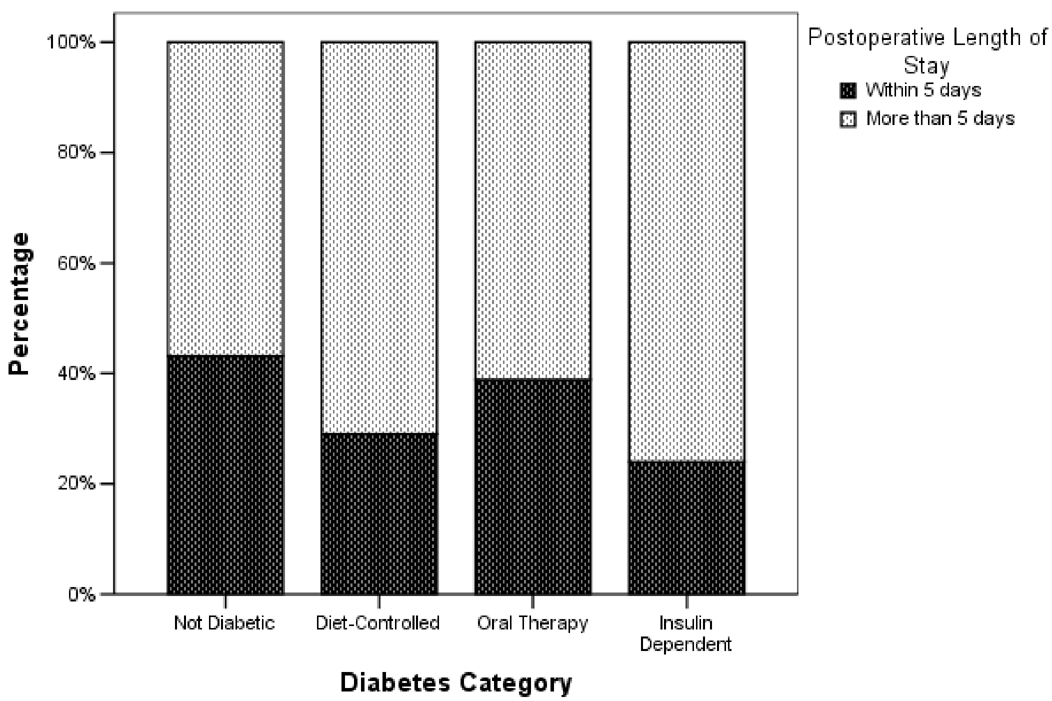


FIGURE 6.2.2.3:

The percentage of patients in each of the discharge groups by diabetic group

There was a significant association between the three diabetic groups and discharge within five days (χ^2 = 14.83; df = 2; p = 0.001) but again the magnitude of difference was low (τ = 0.10; p < 0.001).

Figure 6.2.2.4 illustrates the association between the three diabetic groups and discharge within five days.

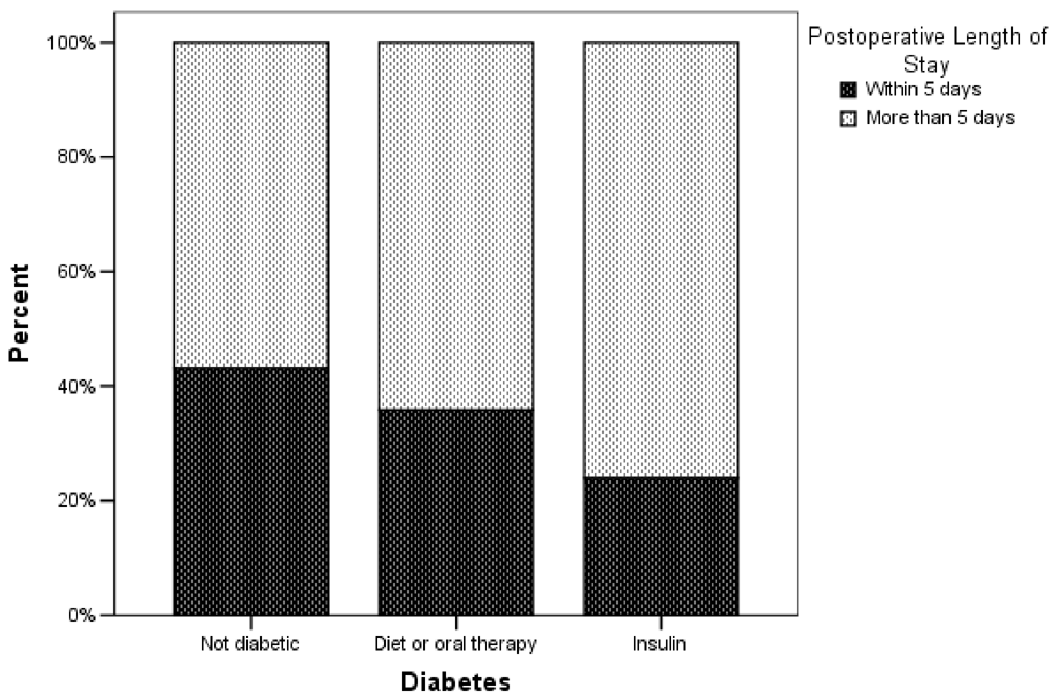


FIGURE 6.2.2.4:

The percentage of patients in each of the discharge groups by diabetic group

There was also a significant association between the presence or absence of diabetes and discharge within five days (χ^2 = 11.02; df = 1; p = 0.001) but the strength of this association was also weak (φ = 0.10; p = 0.001).

HYPERTENSION

Information on hypertension was not recorded for three patients (0.3%). PLOS was not normally distributed for either non-hypertensive (K-S Z = 4.80, $p < 0.001$), or hypertensive patients (K-S Z = 9.84, $p < 0.001$).

Table 6.2.2.2 shows the descriptive statistics for hypertension and PLOS.

TABLE 6.2.2.2:
POSTOPERATIVE LENGTH OF STAY BY THE PRESENCE OR ABSENCE OF HYPERTENSION

Hypertension	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
No	205	4	95	8.23 (9.20)	6 (5-8)	5	83 (40.5)	122 (59.5)
Yes	835	3	242	8.20 (10.23)	6 (5-8)	5	333 (39.9)	502 (60.1)
Missing	3						1	2

Hypothesis 1

There were no differences in the PLOS of patients with or without hypertension (M-W Z = -0.07, p = 0.946).

Hypothesis 2

There was no association between hypertension and discharge within five days ($\chi^2 = 0.03$; df = 1; p = 0.874).

RENAL FUNCTION

Renal function was not recorded for five patients (0.5%). The data on renal function was reduced to either the absence or presence of renal disease and recoded as (1) and (2) respectively as categorising the severity of the renal impairment resulted in some very small groups. PLOS was normally distributed for patients with renal disease (K-S Z = 0.93, $p = 0.359$), but not for those without (K-S Z = 10.89, $p < 0.001$).

Table 6.2.2.3 shows the descriptive statistics for renal function and PLOS.

TABLE 6.2.2.3:
POSTOPERATIVE LENGTH OF STAY BY THE PRESENCE OR ABSENCE OF RENAL DISEASE

Renal Impairment	N	PLOS						
		Min.	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
None	1006	3	242	8.05 (10.12)	6 (5-8)	5	414 (41.2)	592 (58.8)
Yes	32	5	31	13.19 (7.55)	10.5 (6.25-19.5)	6	2 (6.3)	30 (93.8)
Missing	5						1	4

Hypothesis 1

The presence of renal disease was observed to significantly increase PLOS (M-W Z = -5.43, $p < 0.001$).

Hypothesis 2

There was a significant association between the presence or absence of renal disease and discharge within five days ($\chi^2 = 15.73$; df = 1; $p < 0.001$) but the strength of the relationship was weak ($\varphi = 0.12$; $p < 0.001$).

Figure 6.2.2.5 illustrates the association between renal disease and discharge within five days.

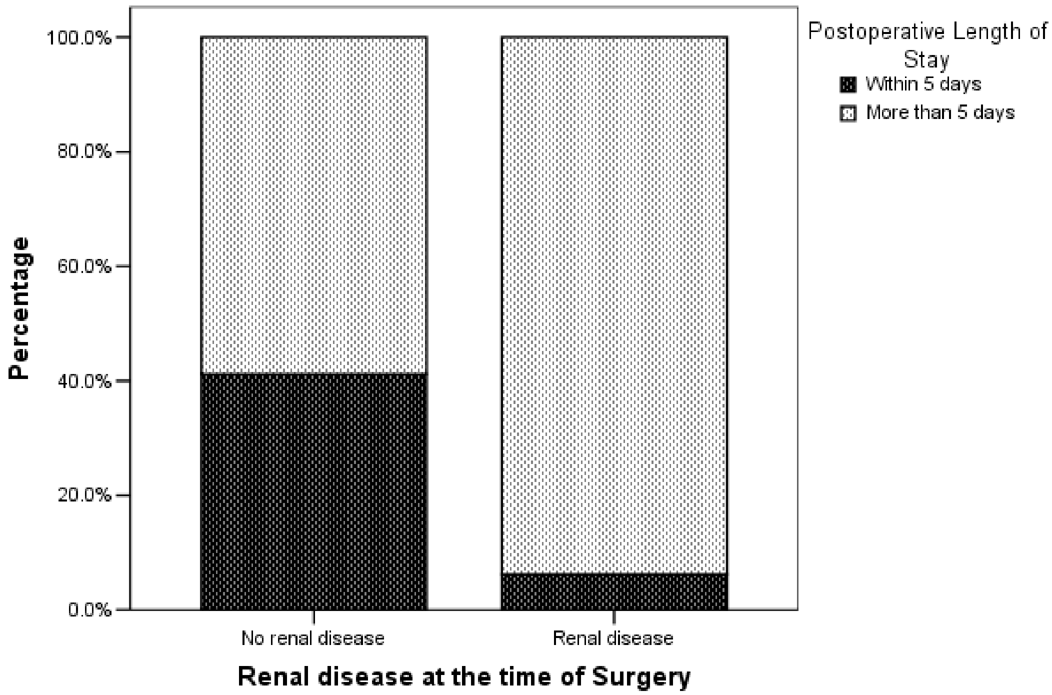


FIGURE 6.2.2.5:

The percentage of patients in each of the discharge groups with and without renal disease

EJECTION FRACTION

The ejection fraction was not recorded for two patients (0.2%). PLOS was not normally distributed within any of the ejection fraction categories; poor (K-S Z = 2.13, $p < 0.001$), fair (K-S Z = 5.55, $p < 0.001$) and good (K-S Z = 9.18, $p < 0.001$).

Table 6.2.2.4 shows the descriptive statistics for ejection fraction and PLOS.

TABLE 6.2.2.4:
POSTOPERATIVE LENGTH OF STAY BY EJECTION FRACTION

Ejection Fraction	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Poor	82	4	31	8.60 (5.02)	7 (5-10)	5	21 (25.6)	61 (74.4)
Fair	329	4	92	8.95 (8.77)	7 (5-9)	5	101 (30.7)	228 (69.3)
Good	630	3	242	7.77 (11.13)	6 (5-8)	5	294 (46.7)	336 (53.3)
Missing	2						1	1

Hypothesis 1

There were significant differences between ejection fraction group and PLOS (K-W $\chi^2 = 31.64$; df = 2; $p < 0.001$). The level of significance was adjusted to $p = 0.017$ for post hoc comparisons.

Patients with a good ejection fraction had a significantly shorter PLOS than those with a poor ejection fraction (M-W Z = -3.75, $p < 0.001$) and a fair ejection fraction (M-W Z = -4.88, $p < 0.001$). Patients with a poor ejection fraction did not differ in PLOS from those with a fair ejection fraction (M-W Z = -0.82, $p = 0.412$).

Figure 6.2.2.6 illustrates the median PLOS for patients in each of the ejection fraction categories.

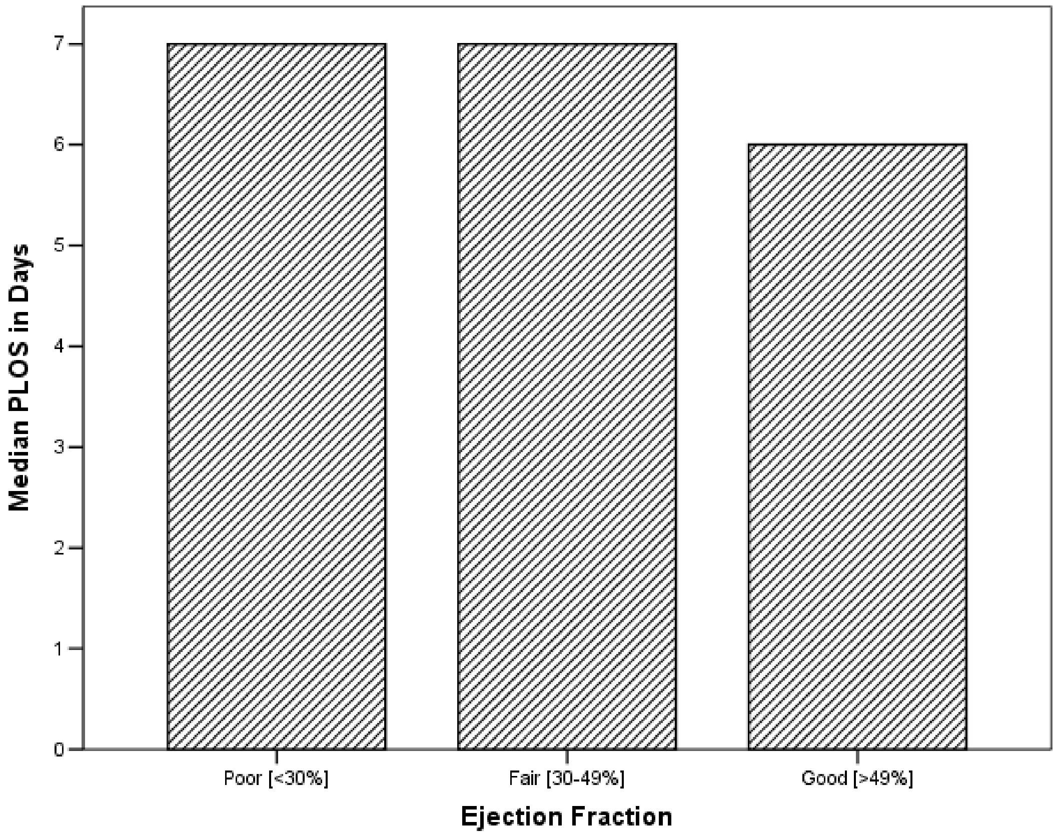


FIGURE 6.2.2.6:

The median postoperative length of stay for patients in each ejection fraction group

Hypothesis 2

There was a significant association between ejection fraction and discharge within five days of surgery ($\chi^2 = 30.61$; df = 2; $p < 0.001$) but the magnitude of difference was low ($\tau = -0.17$; $p < 0.001$).

Figure 6.2.2.7 illustrates the association between ejection fraction and discharge within five days.

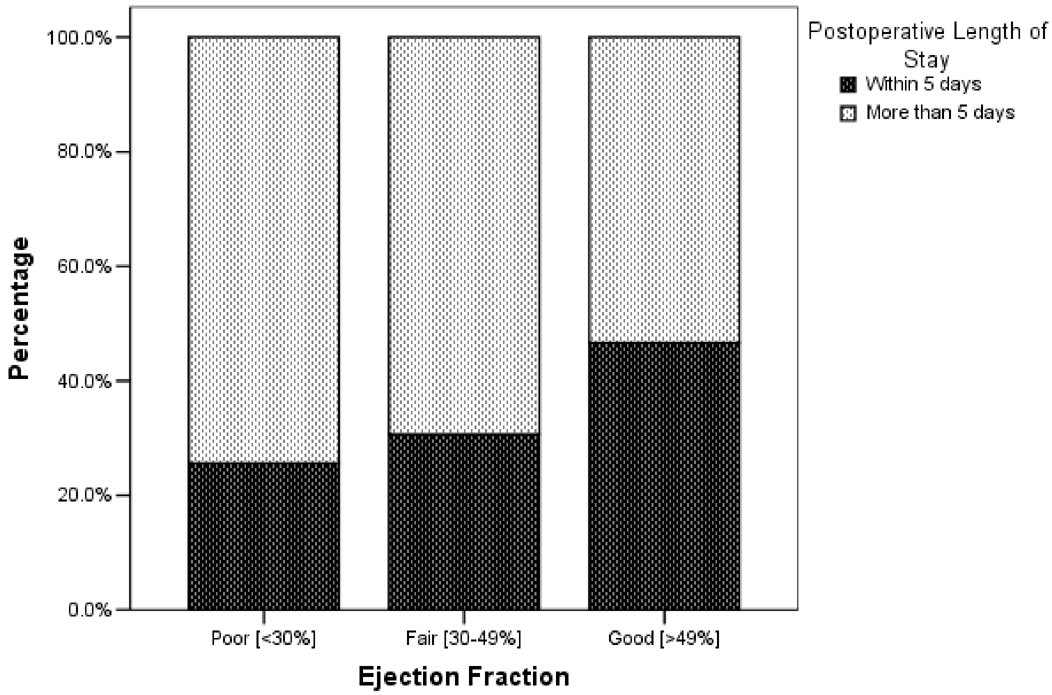


FIGURE 6.2.2.7:

The percentage of patients in each of the discharge groups by ejection fraction

PREVIOUS MYOCARDIAL INFARCTION

The history of previous MI was not recorded for 303 patients (29.1%). Due to the small number of patients with two or more previous MIs, this group was combined with patients who had one previous MI and recoded as (1). PLOS was not normally distributed within either of the MI categories; none (K-S Z = 5.44, $p < 0.001$), one or more MI (K-S Z = 5.62, $p < 0.001$).

Table 6.2.2.5 shows the descriptive statistics for previous MI and PLOS.

TABLE 6.2.2.5:
POSTOPERATIVE LENGTH OF STAY BY PREVIOUS MYOCARDIAL INFARCTION

Number of Previous MI's	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
None	370	4	81	7.66 (6.37)	6 (5-8)	5	161 (43.5)	209 (56.5)
One or more	370	4	92	8.30 (7.39)	6 (5-8)	5	138 (37.3)	232 (62.7)
Missing	303						118	185

Hypothesis 1

There was no significant difference between patients with and without a history of a previous MI and PLOS (M-W Z = -1.77, $p = 0.077$).

Hypothesis 2

There was no significant association between previous MI(s) and discharge within five days of surgery ($\chi^2 = 2.97$; df = 1; $p = 0.085$).

DYSPNOEA CLASSIFICATION

Dyspnoea classification was not recorded for 302 patients (29.0%). Data for patients in the NYHA 4 group were combined that of patients in the NYHA 3 group due to the small number of patients in this group and recoded as (3). PLOS was not normally distributed for any of the dyspnoea classifications; NYHA 1 (K-S Z = 4.22, $p < 0.001$), NYHA 2 (K-S Z = 5.16, $p < 0.001$), or NYHA 3 and 4 combined (K-S Z = 3.60, $p < 0.001$).

Table 6.2.2.6 shows the descriptive statistics for dyspnoea classification and PLOS.

TABLE 6.2.2.6:
POSTOPERATIVE LENGTH OF STAY BY DYSPNOEA CLASSIFICATION

Dyspnoea Class.	N	PLOS						
		Min	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
NYHA 1	261	4	45	7.21 (4.57)	6 (5-8)	5	120 (46.0)	141 (54.0)
NYHA 2	332	4	44	7.63 (5.48)	6 (5-8)	5	132 (39.8)	200 (60.2)
NYHA 3 & 4	148	4	92	10.09 (11.35)	7 (5-10)	5	46 (31.1)	102 (69.0)
Missing	302						119	183

<u>Hypothesis 1</u>

There were significant differences between dyspnoea classification and PLOS (K-W χ^2 = 13.07; df = 2; p = 0.001). The level of significance was adjusted to p = 0.016 for post hoc comparisons.

NYHA 1 did not differ significantly in PLOS from NHYA 2 (M-W Z = -1.12, p = 0.263), but did differ from NYHA 3 and 4 (M-W Z = -3.49, p < 0.001). NYHA 2 was significantly different in PLOS from NHYA 3 and 4 (M-W Z = -2.86, p = 0.004).

Figure 6.2.2.8 illustrates the median PLOS for dyspnoea classification.

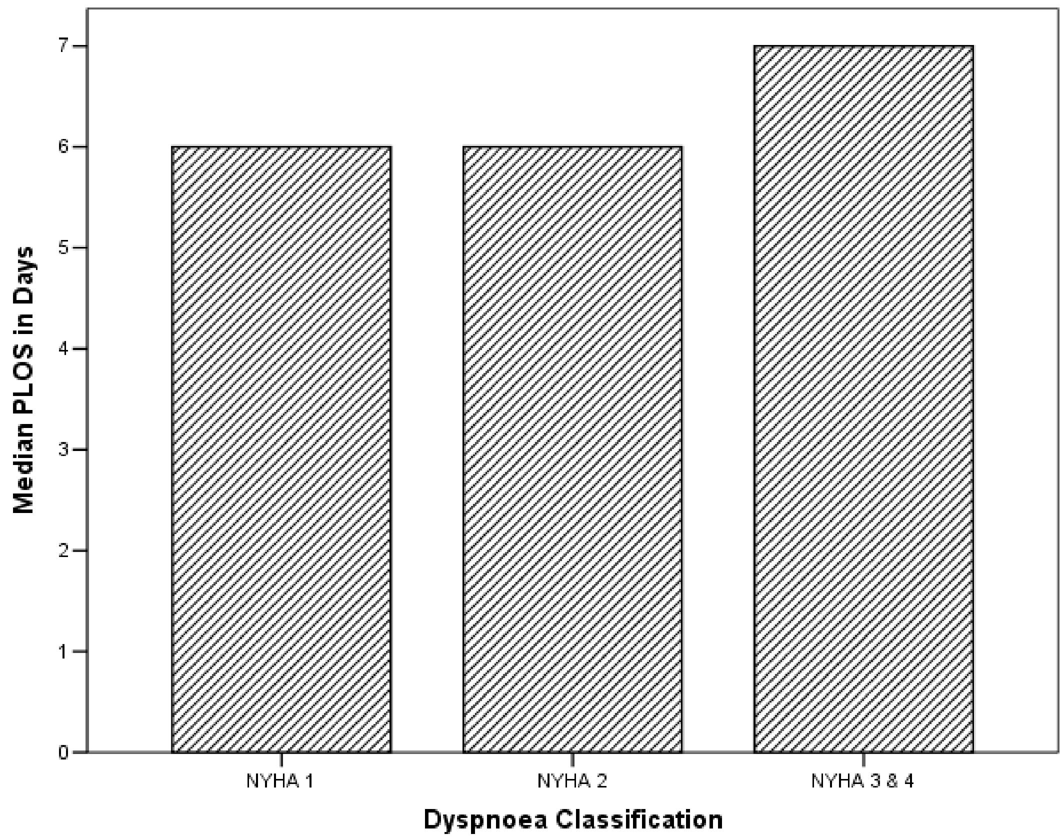


FIGURE 6.2.2.8:

The median postoperative length of stay by dyspnoea classification

Hypothesis 2

There was a significant association between dyspnoea classification and discharge within five days of surgery (χ^2 = 8.77; df = 2; p = 0.012) but the strength of the association was low (τ = 0.11; p = 0.003).

Figure 6.2.2.9 illustrates the association between dyspnoea classification and discharge within five days.

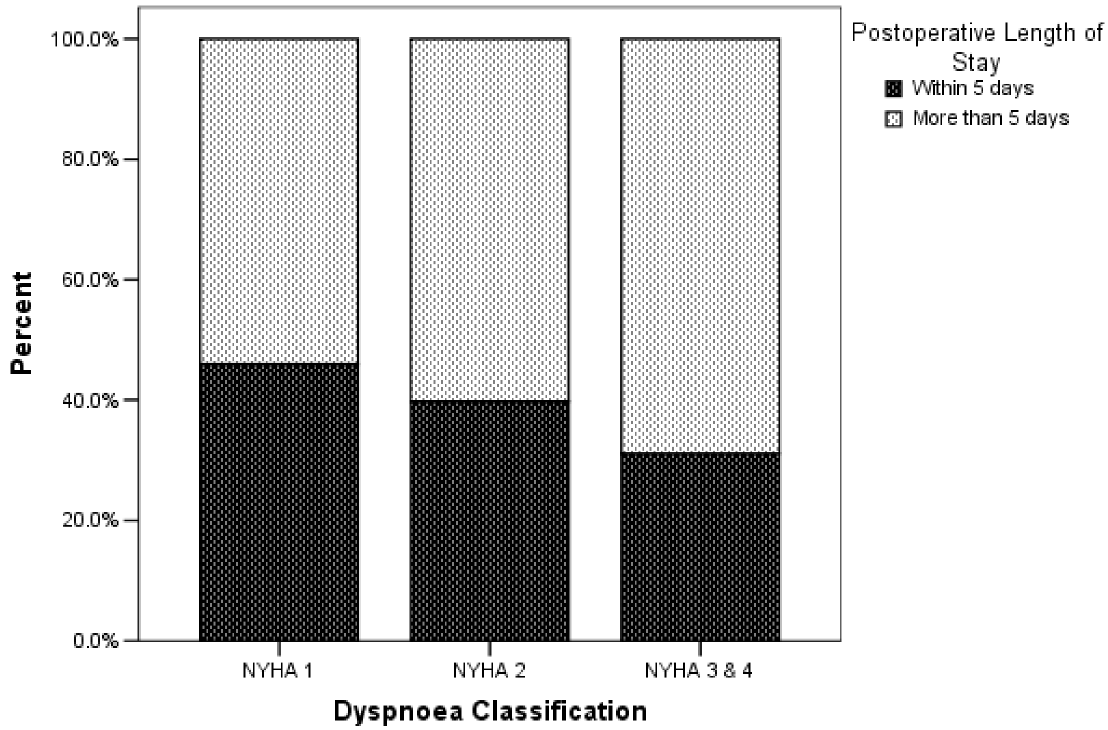


FIGURE 6.2.2.9:

The percentage of patients in each of the discharge groups by dyspnoea classification

ANGINA CLASSIFICATION

Angina classification was not recorded for 301 patients (28.9%). Due to the small number of patients with an angina classification of CCS 0 and CCS 4, these groups were combined with CCS 1 and CCS 3 and recoded (1) and (3) respectively. PLOS was not normally distributed within any of the classifications; CCS 0 and 1 (K-S Z = 3.49, p < 0.001), CCS 2 (K-S Z = 4.49, p < 0.001), CCS 3 and 4 (K-S Z = 5.11, p < 0.001).

Table 6.2.2.7 shows the descriptive statistics for angina classification and PLOS.

TABLE 6.2.2.7:
POSTOPERATIVE LENGTH OF STAY BY ANGINA CLASSIFICATION

Angina Classification	N	PLOS						
		Min	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
CCS 0 & 1	165	4	45	7.95 (5.73)	6 (5-8)	5	62 (37.6)	103 (62.4)
CCS 2	276	4	43	7.12 (4.76)	6 (5-7)	5	132 (47.8)	144 (52.2)
CCS 3 & 4	301	4	92	8.75 (8.79)	6 (5-9)	5	105 (34.9)	196 (65.1)
Missing	301						118	183

Hypothesis 1

There were significant differences between angina classification and PLOS (K-W $\chi^2 = 13.04$; df = 2; p = 0.001). The level of significance was adjusted to p = 0.016 for the following post hoc comparisons.

CCS 0 and 1 did not differ significantly in PLOS from CCS 2 (M-W Z = -2.11, p = 0.035), or CCS 3 and 4 (M-W Z = -0.995, p = 0.320). CCS 2 differed significantly in PLOS from CCS 3 and 4 (M-W Z = -3.55, p < 0.001).

Hypothesis 2

There was a significant association between angina classification and discharge within five days of surgery ($\chi^2 = 10.68$; df = 2; p = 0.011). However, the strength of the association was not significant ($\tau = 0.05$, p = 0.160).

Figure 6.2.2.10 illustrates the association between angina classification and discharge within five days.

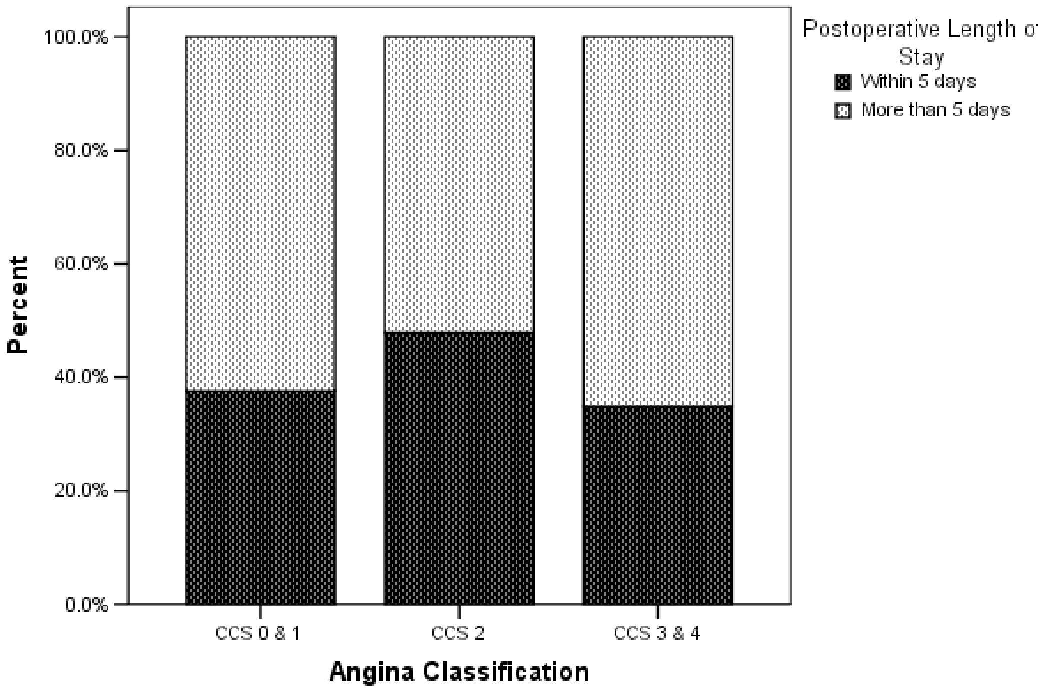


FIGURE 6.2.2.10:

The percentage of patients in each of the discharge groups by dyspnoea classification

PERIPHERAL VASCULAR DISEASE

Information on PVD was not recorded for two patients (0.2%). PLOS was not normally distributed for either those patients with (K-S Z = 4.68, $p < 0.001$), or without PVD (K-S Z = 8.49, $p < 0.001$).

Table 6.2.2.8 shows the descriptive statistics for PVD and PLOS.

TABLE 6.2.2.8:
POSTOPERATIVE LENGTH OF STAY BY PERIPHERAL VASCULAR DISEASE

PVD	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
No	886	3	95	7.81 (6.67)	6 (5-8)	5	375 (43.3)	511 (57.7)
Yes	155	4	242	10.49 (20.57)	7 (5-9)	5	41 (26.5)	114 (73.5)
Missing	2						1	1

Hypothesis 1

PVD was observed to significantly increase PLOS (M-W Z = -4.07, $p < 0.001$).

Hypothesis 2

There was a significant association between PVD and discharge within five days ($\chi^2 = 13.85$; df = 1; $p < 0.001$) but the strength of the association was weak ($\varphi = 0.12$; $p < 0.001$).

Figure 6.2.2.11 illustrates the association between PVD and discharge within five days.

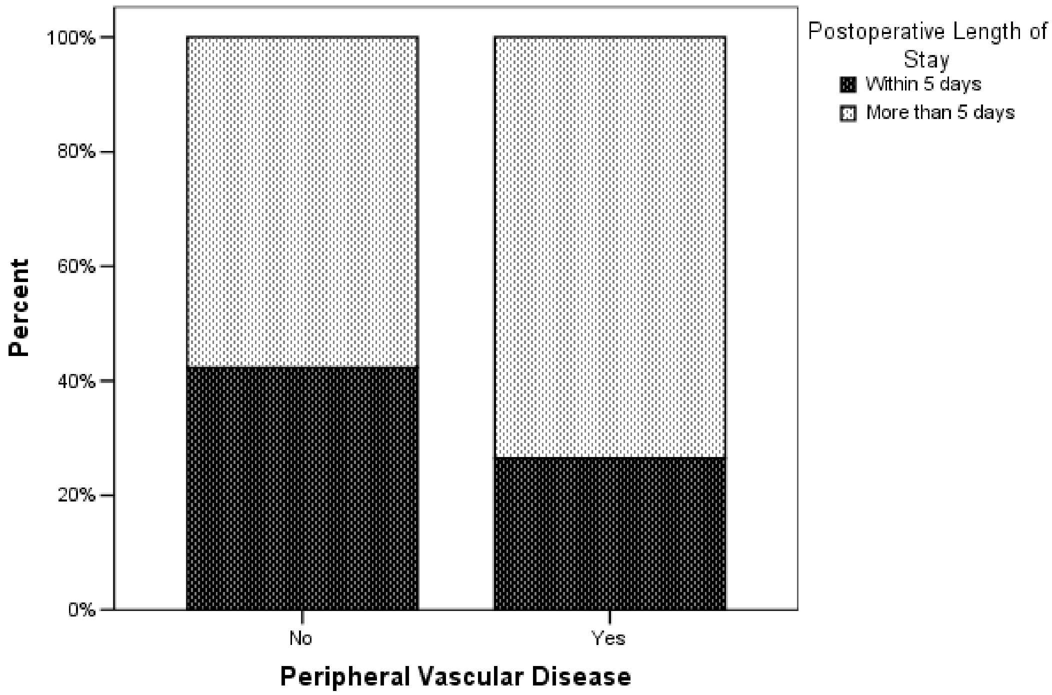


FIGURE 6.2.2.11:

The percentage of patients in each of the discharge groups with and without peripheral vascular disease

PULMONARY DISEASE

The history of pulmonary disease was not recorded for two patients (0.2%). Due to the small number patients with asthma this group was combined with patients with COPD/emphysema and recoded as (1). PLOS was not normally distributed for either those patients with (K-S Z = 2.96, $p < 0.001$), or without pulmonary disease (K-S Z = 10.54, $p < 0.001$).

Table 6.2.2.9 shows the descriptive statistics for pulmonary disease and PLOS.

TABLE 6.2.2.9:
POSTOPERATIVE LENGTH OF STAY BY PULMONARY DISEASE HISTORY

Pulmonary Disease	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
None	919	3	242	8.05 (10.42)	6 (5-8)	5	386 (42.0)	533 (58.0)
Yes	122	4	45	9.39 (6.86)	7 (5.75-10)	5	30 (24.6)	92 (75.4)
Missing	2						1	1

Hypothesis 1

Patients with no history of pulmonary disease had significantly shorter PLOS than patients with pulmonary disease (M-W Z = -4.73, $p < 0.001$).

Hypothesis 2

There was also a significant association between pulmonary disease history and discharge within five days ($\chi^2 = 13.61$; df = 1; $p < 0.001$) but the strength of the relationship was low ($\varphi = 0.11$; $p < 0.001$).

Figure 6.2.2.12 illustrates the association between pulmonary disease history and discharge within five days.

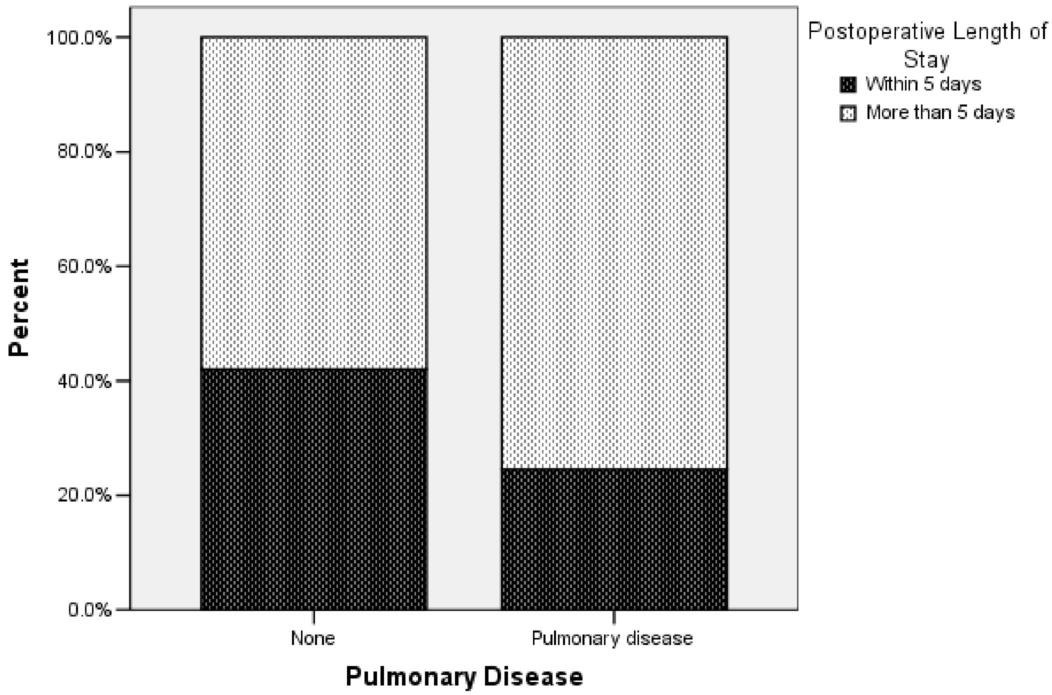


FIGURE 6.2.2.12:

The percentage of patients in each of the discharge groups by their pulmonary disease history

SMOKING HISTORY

The smoking history was not recorded for 308 patients (29.5%). PLOS was not normally distributed patients who had never smoked (K-S Z = 3.75, $p < 0.001$), were ex-smokers (K-S Z = 6.47, $p < 0.001$), or current smokers (K-S Z = 2.75, $p < 0.001$).

Table 6.2.2.10 shows the descriptive statistics for smoking history and PLOS.

TABLE 6.2.2.10:
POSTOPERATIVE LENGTH OF STAY BY SMOKING HISTORY

Smoking History	N	PLOS						
		Min	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Never smoked	184	4	45	8.04 (5.90)	6 (5-8)	5	72 (39.1)	112 (60.9)
Ex-smoker	493	4	92	7.90 (7.10)	6 (5-8)	5	201 (40.8)	292 (59.2)
Current smoker	58	4	55	8.69 (8.30)	6 (5-8)	5	22 (37.9)	36 (62.1)
Missing	308						122	186

Hypothesis 1

There were no differences in PLOS between patients who had never smoked, ex-smokers or current smokers (K-W $\chi^2 = 0.31$; df = 2; p = 0.856).

Hypothesis 2

There was no association between smoking history and discharge within five days ($\chi^2 = 0.28$; df = 2; p = 0.870).

Table 6.2.11 summarises the univariate test results for co-morbidity variables.

TABLE 6.2.11:
SUMMARY OF UNIVARIATE TEST RESULTS FOR CO-MORBIDITY VARIABLES

Variable	Groups	N	% of total	PLOS ≤ 5 days (n)	PLOS > 5 days (n)	Association with PLOS	Association with PLOS ≤ 5 days
Diabetes	Not diabetic Diet or oral therapy Insulin Missing	744 201 96 2	71.3 19.3 9.2 0.2	321 72 23 1	423 129 73 1	K-W χ2 = 22.55, df = 2; p < 0.001	χ2 = 14.83, df = 2; p = 0.001 τ = 0.10; p < 0.001
Hypertension	No Yes Missing	205 835 3	19.7 80.1 0.3	83 333 1	122 502 2	M-W Z = -0.07, p = 0.946	χ2 = 0.03, df = 1; p = 0.874
Renal Disease	No Yes Missing	1006 32 5	96.5 3.1 0.5	414 2 1	592 30 4	M-W Z = -5.43, p < 0.001	χ2 = 15.73, df = 1; p < 0.001 φ = 0.12; p < 0.001
Ejection Fraction	Poor Fair Good Missing	82 329 630 2	7.9 31.5 60.4 0.2	21 101 294 1	61 228 336 1	K-W χ2 = 31.64, df = 2; p < 0.001	χ2 = 30.61, df = 2; p < 0.001 τ = -0.17; p < 0.001
No. Previous MI's	None One or more Missing	370 370 303	35.5 35.5 29.1	161 138 118	209 232 185	M-W Z = -1.77, p = 0.077	χ2 = 2.97, df = 1; p = 0.085
Dyspnoea Classification	NYHA 1 NYHA 2 NYHA 3 & 4 Missing	261 332 148 303	25.0 31.8 14.2 29.0	120 132 46 119	141 200 102 183	K-W χ2 = 13.07, df = 2; p = 0.001	χ2 = 8.77, df = 2; p = 0.012 τ = 0.11; p = 0.003
Angina Classification	CCS 0 & 1 CCS 2 CCS 3 & 4 Missing	165 276 301 301	15.8 26.5 28.9 28.9	62 132 105 118	103 144 196 183	K-W χ2 = 13.04, df = 2; p = 0.001	χ2 = 10.68, df = 2; p = 0.005 τ = 0.05, p = 0.160
Peripheral Vascular Disease	No Yes Missing	886 155 2	84.9 14.9 0.2	375 41 1	511 114 1	M-W Z = -4.07, p < 0.001	χ2 = 13.85, df = 1; p < 0.001 φ = 0.12; p < 0.001

Pulmonary Disease	None Asthma/COPD/emphysema Missing	919 122 2	88.1 11.7 0.2	386 30 1	533 92 1	M-W Z = -4.73, p < 0.001	χ2 = 13.61, df = 1; p < 0.001 φ = 0.11; p < 0.001
Smoking	Never smoked Ex-smoker Current smoker Missing	184 493 58 308	17.6 47.3 5.6 29.5	72 201 22 122	112 292 36 186	K-W χ2 = 0.31, df = 2; p = 0.856	χ2 = 0.28, df = 2; p = 0.870

6.2.3 SEVERITY OF ILLNESS

LEFT MAIN STEM DISEASE

Information on LMS disease was not recorded for 349 patients (33.5%). PLOS was not normally distributed for either those patients with (K-S Z = 4.23, $p < 0.001$), or without LMS disease (K-S Z = 6.42, $p < 0.001$).

Table 6.2.3.1 shows the descriptive statistics for LMS disease and PLOS.

TABLE 6.2.3.1:
POSTOPERATIVE LENGTH OF STAY BY LEFT MAIN STEM DISEASE

LMS Disease	N	PLOS						
		Min	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
No	479	4	92	7.93 (7.16)	6 (5-8)	5	201 (42.0)	278 (58.0)
Yes	215	4	55	8.13 (6.46)	6 (5-8)	5	76 (35.3)	139 (64.7)
Missing	349						140	209

Hypothesis 1

There were no differences in the PLOS of patients without LMS disease or LMS disease less than 51% of diameter stenosis, and LMS disease greater than 50% of diameter stenosis (M-W Z = -1.22, $p = 0.222$).

Hypothesis 2

There was no association between LMS disease and discharge within five days ($\chi^2 = 2.71$; df = 1; $p = 0.100$).

NUMBER OF VESSELS BYPASSED

The number of vessels bypassed was not recorded for 20 patients (1.9%). Due to the small number of patients who had one or five vessels bypassed, these patients were grouped with patients who had two and four vessels bypassed and recoded as (1) and (4) respectively. PLOS was not normally distributed by the number of vessels bypassed; one or two vessels (K-S Z = 4.48, p = 0.001), three vessels (K-S Z = 8.05, p < 0.001), and four or five vessels (K-S Z = 5.14, p < 0.001).

Table 6.2.3.2 shows the descriptive statistics for the number of vessels bypassed and PLOS.

TABLE 6.2.3.2:
POSTOPERATIVE LENGTH OF STAY BY THE NUMBER OF VESSELS BYPASSED

No. of Vessels Bypassed	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
1 or 2	221	3	95	7.69 (7.27)	6 (5-8)	5	96 (43.4)	125 (56.6)
3	507	4	242	8.54 (12.40)	6 (5-8)	5	206 (40.6)	301 (59.4)
4 or 5	295	4	81	7.99 (6.86)	6 (5-8)	5	107 (36.3)	188 (63.7)
Missing	20						8	12

Hypothesis 1

There was no difference in PLOS by the number of vessels bypassed (K-W χ^2 = 1.67; df = 2; p = 0.434).

Hypothesis 2

There was no association between the number of vessels bypassed and discharge within five days (χ^2 = 2.88; df = 2; p = 0.237).

PARSONNET SCORE – from Hard Data

Parsonnet scores were not recorded for three patients (0.3%). The mean Parsonnet score was 9.32 (sd 6.43) and the distribution within the sample was not normally distributed (K-S Z = 4.28, $p < 0.001$).

PLOS was not normally distributed within any of the Parsonnet risk groups; 1% (K-S Z = 5.44, $p < 0.001$), 5% (K-S Z = 6.46, $p < 0.001$), 9% (K-S Z = 4.28, $p < 0.001$), 17% (K-S Z = 3.86, $p < 0.001$), and 31% (K-S Z = 2.44, $p < 0.001$).

Table 6.2.3.3 shows the descriptive statistics for Parsonnet score from hard data and PLOS.

TABLE 6.2.3.3:
POSTOPERATIVE LENGTH OF STAY BY PARSONNET SCORE FROM HARD DATA

Parsonnet Risk	N	PLOS						
		Min	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
1%	288	3	95	7.01 (6.63)	5 (5-7)	5	153 (53.1)	136 (47.2)
5%	281	4	242	8.54 (15.38)	6 (5-8)	5	121 (43.1)	162 (57.7)
9%	220	4	55	7.97 (6.21)	6 (5-8)	5	80 (36.4)	139 (63.2)
17%	168	4	92	9.15 (8.42)	7 (5-9)	5	43 (25.6)	124 (73.8)
31%	83	4	45	9.95 (8.23)	7 (6-10.5)	5	18 (21.7)	64 (77.1)
Missing	3						2	1

Hypothesis 1

There was a small but significant association between Parsonnet score and PLOS ($r_s = 0.24$; $n = 938$; $p < 0.001$). There was also a significant difference between Parsonnet risk category and PLOS (K-W $\chi^2 = 64.63$; $df = 4$; $p < 0.001$). The level of significance was adjusted to $p = 0.005$ for post hoc comparisons.

Patients with a 1% risk did not differ significantly in PLOS from those with a 5%

risk (M-W $Z = -2.33$, $p = 0.02$) but did differ from patients with a 9% risk (M-W $Z = -3.66$, $p < 0.001$), 17% risk (M-W $Z = -6.71$, $p < 0.001$), and 31% risk (M-W $Z = -5.75$, $p < 0.001$).

Patients with a 5% risk did not differ significantly in PLOS from those with a 9% risk (M-W $Z = -1.39$, $p = 0.164$), but differed from those with a 17% risk (M-W $Z = -4.67$, $p < 0.001$), and 31% risk (M-W $Z = -4.16$, $p < 0.001$).

Patients with a 9% risk differed significantly in PLOS from those with a 17% risk (M-W $Z = -3.41$, $p = 0.001$), and a 31% risk (M-W $Z = -3.24$, $p = 0.001$).

Patients with a 17% risk did not differ significantly from those with a 31% risk (M-W $Z = -0.69$, $p = 0.489$).

Figure 6.2.3.1 illustrates the median PLOS for each of the Parsonnet risk categories.

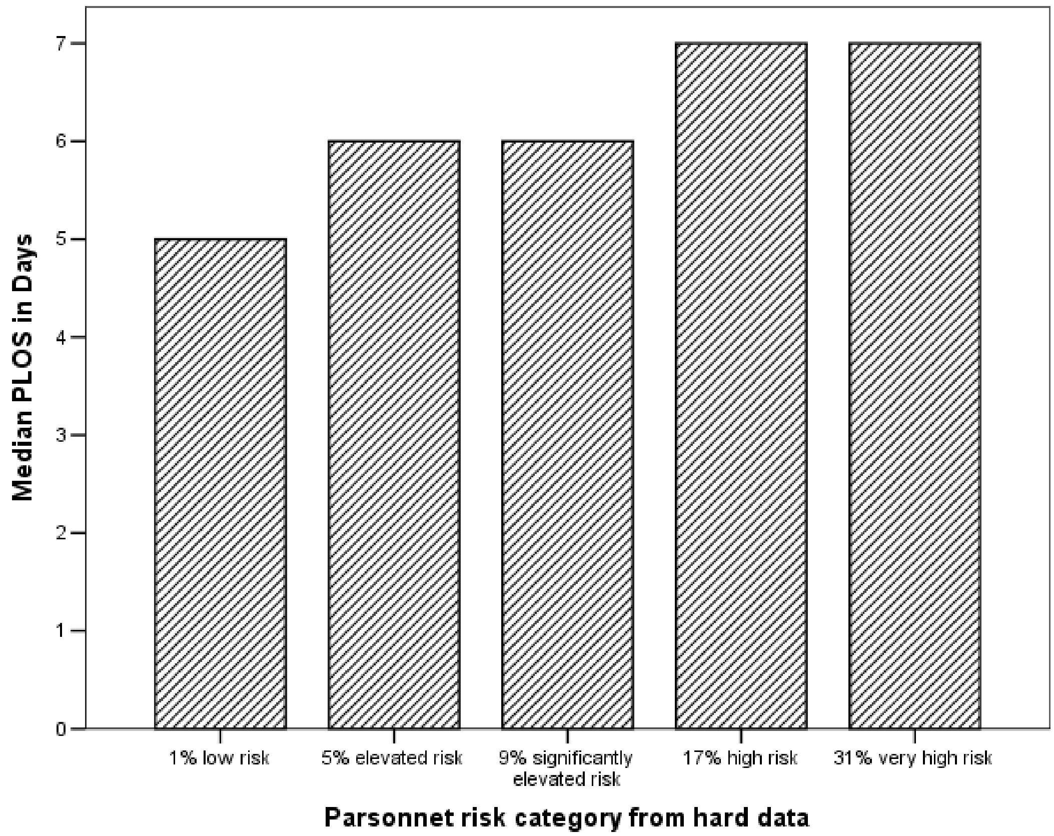


FIGURE 6.2.3.1:

The median postoperative length of stay for patients in each of the Parsonnet risk categories

Hypothesis 2

The mean Parsonnet scores of patients discharged within and after five days of surgery were 7.59 (sd 5.64) and 10.46 (sd 6.66) respectively. Parsonnet scores were not normally distributed for either those discharged within five days (K-S Z = 3.52, $p < 0.001$), or those discharged after five days (K-S Z = 2.62, $p < 0.001$).

There was a significant difference in the Parsonnet scores of those discharged within five days and those who had a longer PLOS (M-W Z = -7.03, $p < 0.001$). There was also a significant association between Parsonnet risk category and discharge within five days of surgery ($\chi 2 = 47.46$; df = 4; $p < 0.001$). However, the strength of the association was low ($\tau = 0.23$; $p < 0.001$).

Figure 6.2.3.2 illustrates the association between Parsonnet risk category and discharge within five days.

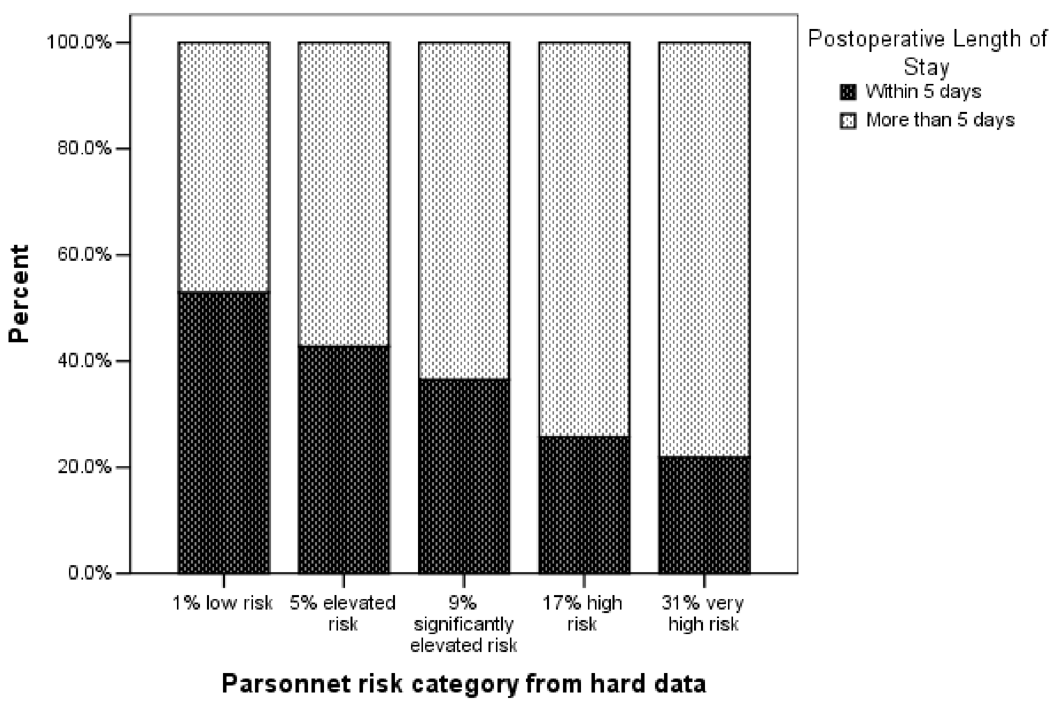


FIGURE 6.2.3.2:

The percentage of patients in each of the discharge groups by Parsonnet risk category

PARSONNET SCORE - With Catastrophic States and Other Rare Conditions Included

Parsonnet scores were not recorded for three patients (0.3%). The mean Parsonnet score was 9.35 (sd 6.44). Parsonnet scores within the sample were not normally distributed (K-S Z = 4.27, $p < 0.001$).

PLOS was not normally distributed within any of the Parsonnet risk groups; 1% (K-S Z = 5.45, $p < 0.001$), 5% (K-S Z = 6.43, $p < 0.001$), 9% (K-S Z = 4.22, $p < 0.001$), 17% (K-S Z = 3.87, $p < 0.001$), and 31% (K-S Z = 2.45, $p < 0.001$).

Table 6.2.3.4 shows the descriptive statistics for Parsonnet score with catastrophic states and other rare conditions included and PLOS.

TABLE 6.2.3.4:
POSTOPERATIVE LENGTH OF STAY BY PARSONNET SCORE WITH CATASTROPHIC STATES AND OTHER RARE CONDITIONS

Parsonnet Risk	N	PLOS						
		Min	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
1%	289	3	95	7.04 (6.63)	5 (5-7)	5	153 (52.9)	135 (46.7)
5%	283	4	242	8.53 (15.33)	6 (5-8)	5	120 (42.4)	161 (56.9)
9%	219	4	55	7.95 (6.21)	6 (5-8)	5	81 (37.0)	139 (63.5)
17%	167	4	92	9.17 (8.44)	7 (5-9)	5	43 (25.7)	125 (74.9)
31%	82	4	45	10.00 (8.27)	7 (6-10.25)	5	18 (22.0)	65 (79.3)
Missing	3						2	1

Hypothesis 1

There was a significant but small association between Parsonnet score and PLOS ($r_s = 0.24$; $n = 938$; $p < 0.001$). There was also a significant difference between Parsonnet risk category and PLOS (K-W $\chi^2 = 65.54$; df = 4; $p < 0.001$). The level of significance was adjusted to $p = 0.005$ for post hoc comparisons.

Patients with a 1% risk did not differ significantly in PLOS from those with a 5%

risk (M-W $Z = -2.41$, $p = 0.016$), but did differ from patients with a 9% risk (M-W $Z = -3.75$, $p < 0.001$), 17% risk (M-W $Z = -6.81$, $p < 0.001$), and 31% risk (M-W $Z = -5.80$, $p < 0.001$).

Patients with a 5% risk did not differ significantly in PLOS from those with a 9% risk (M-W $Z = -1.40$, $p = 0.162$), but differed from those with a 17% risk (M-W $Z = -4.66$, $p < 0.001$), and 31% risk (M-W $Z = -4.12$, $p < 0.001$).

Patients with a 9% risk differed significantly in PLOS from those with a 17% risk (M-W $Z = -3.38$, $p = 0.001$), and a 31% risk (M-W $Z = -3.16$, $p = 0.002$).

Patients with a 17% risk did not differ significantly in PLOS from those with a 31% risk (M-W $Z = -0.63$, $p = 0.526$).

Figure 6.2.3.3 illustrates the median PLOS for each of the Parsonnet risk categories.

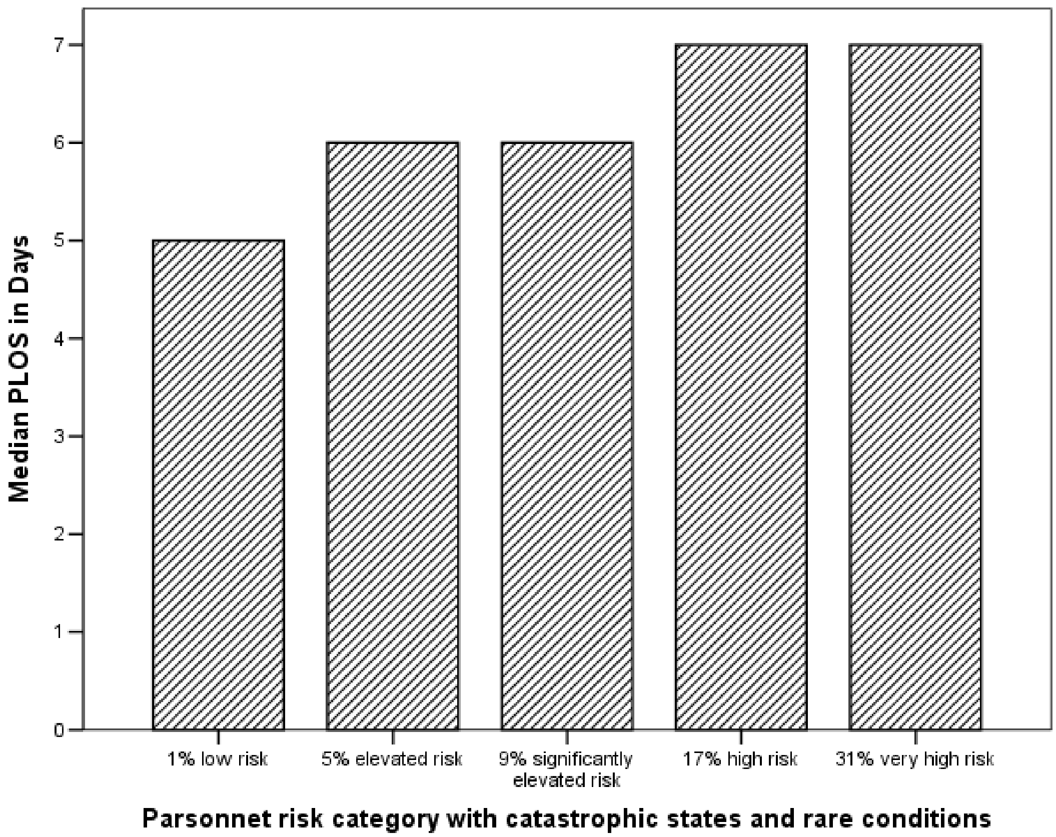


FIGURE 6.2.3.3:

The median postoperative length of stay by Parsonnet risk category

Hypothesis 2

The mean Parsonnet scores of patients discharged within and after five days of surgery were 7.61 (sd 5.64) and 10.51 (sd 6.67) respectively. Parsonnet scores were not normally distributed for either those discharged within five days (K-S Z = 3.50, $p < 0.001$), or those discharged after five days (K-S Z = 2.63, $p < 0.001$).

There was a significant difference in the Parsonnet scores of those discharged within five days and those who had a longer PLOS (M-W Z = -7.09, $p < 0.001$). There was also a significant association between Parsonnet risk category and discharge within five days of surgery (χ^2 = 48.62; df = 4; $p < 0.001$). However, the strength of the association was low (τ = 0.24; $p < 0.001$).

Figure 6.2.3.4 illustrates the association between Parsonnet risk category and discharge within five days.

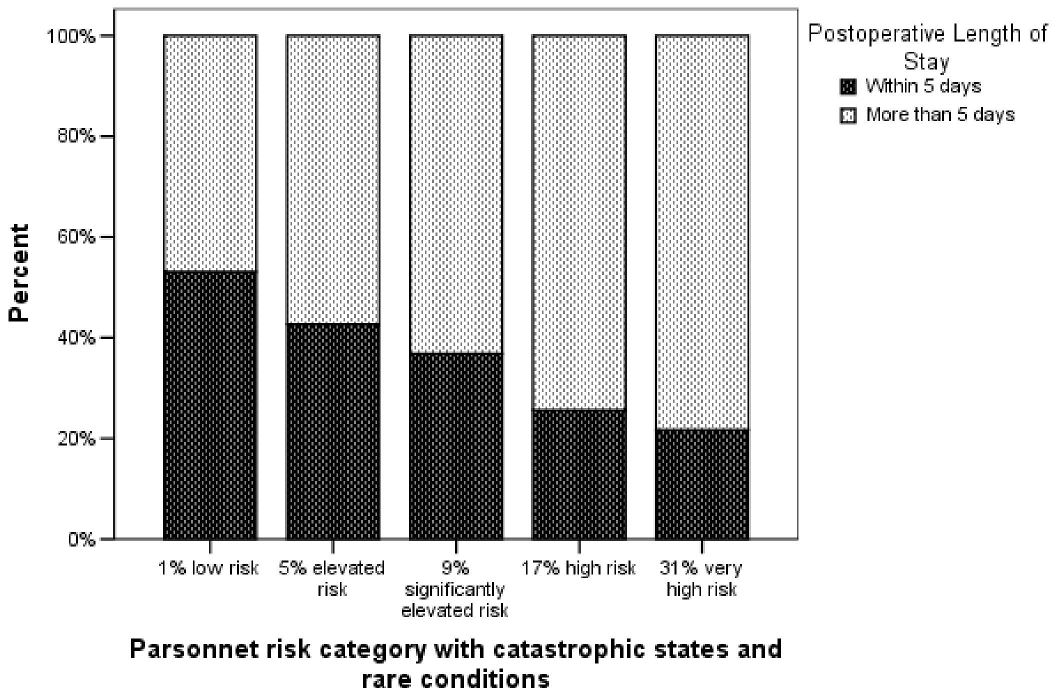


FIGURE 6.2.3.4:

The percentage of patients in each of the discharge groups by Parsonnet risk category

EUROSCORE

EuroSCORE's were not recorded for 19 patients (1.8%). The mean EuroSCORE value was 4.02 (sd 2.86) and the distribution was not normally distributed (K-S Z = 4.20, $p < 0.001$). PLOS was not normally distributed within any of the EuroSCORE risk groups; low risk (K-S Z = 5.96, $p < 0.001$), moderate risk (K-S Z = 5.75, $p < 0.001$), and high risk (K-S Z = 4.34, $p < 0.001$).

Table 6.2.3.5 shows the descriptive statistics for EuroSCORE and PLOS.

TABLE 6.2.3.5:
POSTOPERATIVE LENGTH OF STAY BY EUROSCORE

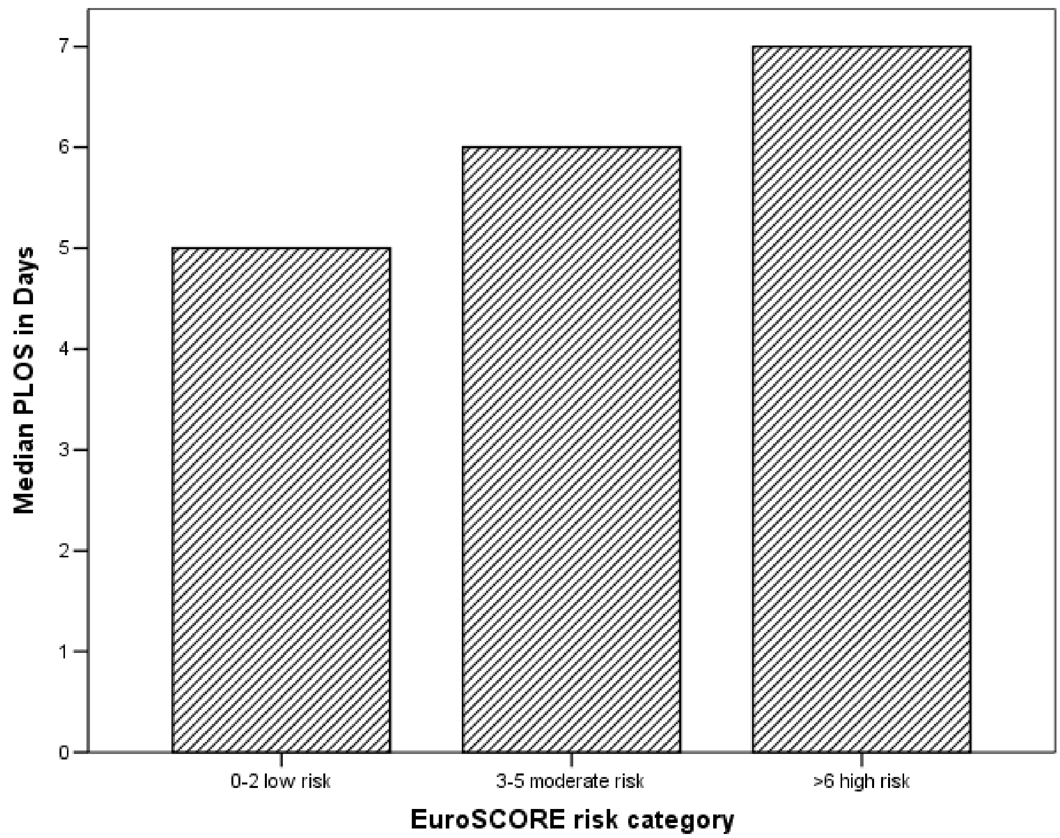
EuroSCORE risk category	**N**	**PLOS**						
		Min.	**Max.**	**Mean (s.d)**	**Median (IQR)**	**Mode**	**≤ 5 days n (%)**	**> 5 days n (%)**
low	315	3	95	7.26 (7.84)	5 (5-7)	5	174 (55.2)	141 (44.8)
mod	462	4	55	7.69 (5.31)	6 (5-8)	5	180 (39.0)	282 (61.0)
high	247	4	92	9.49 (8.43)	7 (6-9)	5	56 (22.7)	191 (77.3)
Missing	19						7	12

Hypothesis 1

There was a small significant association between EuroSCORE and PLOS (r_s = 0.29; n = 925; $p < 0.001$). There was also a significant difference between EuroSCORE risk category and PLOS (K-W χ^2 = 72.591; df = 2, $p < 0.001$). The level of significance was adjusted to $p = 0.017$ for post hoc comparisons.

Patients with a low risk differed in PLOS from both those with a moderate risk (M-W Z = -4.91, $p < 0.001$), and a high risk (M-W Z = -8.29, $p < 0.001$). Patients with a moderate risk differed in PLOS from those with a high risk (M-W Z = -4.90, $p < 0.001$).

Figure 6.2.3.5 illustrates the median PLOS for patients in each EuroSCORE risk category.



<u>FIGURE 6.2.3.5:</u>

<u>The median postoperative length of stay by EuroSCORE risk category</u>

Hypothesis 2

The mean EuroSCORE's of patients discharged within and after five days of surgery were 3.11 (sd 2.36) and 4.62 (sd 3.01) respectively. The EuroSCORE's were not normally distributed for either those discharged within five days (K-S Z = 2.52, $p < 0.001$), or those discharged after five days (K-S Z = 3.44, $p < 0.001$).

There was a significant difference in the EuroSCORE's of those discharged within five days and those who had a longer PLOS (M-W Z = -8.28; $p < 0.001$). There was also a significant association between EuroSCORE risk category and discharge within five days of surgery ($\chi^2 = 61.57$; df = 2; $p < 0.001$) but the strength of the association was low ($\tau = 0.26$; $p < 0.001$).

Figure 6.2.3.6 illustrates the association between EuroSCORE risk category and discharge within five days.

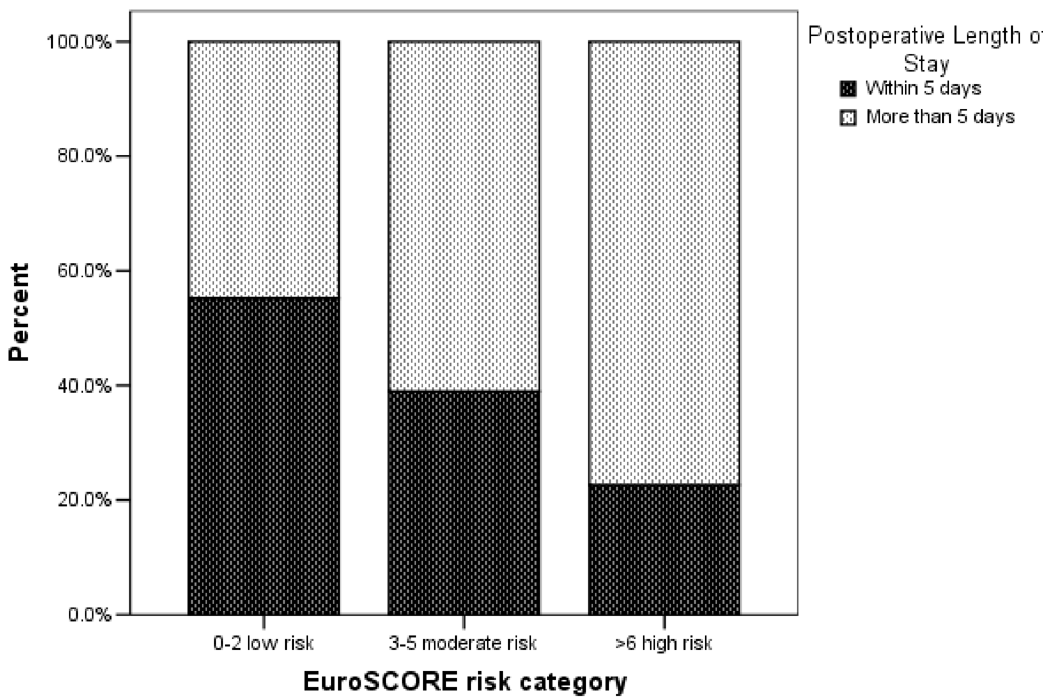


FIGURE 6.2.3.6:

The percentage of patients in each of the discharge groups by EuroSCORE risk category

URGENCY OF SURGERY

Data on the urgency of surgery was not recorded for two patients (0.2%). Due to very small numbers of patients undergoing emergency and salvage surgery, the data was reclassified to elective and non-elective operations and recoded as (1) and (2) respectively. PLOS was not normally distributed for either elective (K-S Z = 8.16, $p < 0.001$), or non-elective surgery (K-S Z = 6.12, $p < 0.001$).

Table 6.2.3.6 shows the descriptive statistics for the urgency of surgery and PLOS.

TABLE 6.2.3.6:
POSTOPERATIVE LENGTH OF STAY BY URGENCY OF SURGERY

Urgency of surgery	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Elective	756	3	95	7.76 (7.09)	6 (5-8)	5	326 (43.1)	430 (56.9)
Non-elective	285	4	242	9.40 (15.37)	7 (5-9)	5	90 (31.6)	195 (68.4)
Missing	2						1	1

Hypothesis 1

Non-elective surgery was observed to significantly increase PLOS (M-W Z = -3.77, $p < 0.001$).

Hypothesis 2

There was also a significant association between the urgency of surgery and discharge within five days ($\chi^2 = 11.49$; df = 1; $p = 0.001$) but the strength of the association was weak ($\varphi = 0.11$; $p = 0.001$).

Figure 6.2.3.7 illustrates the association between urgency of surgery and discharge within five days.

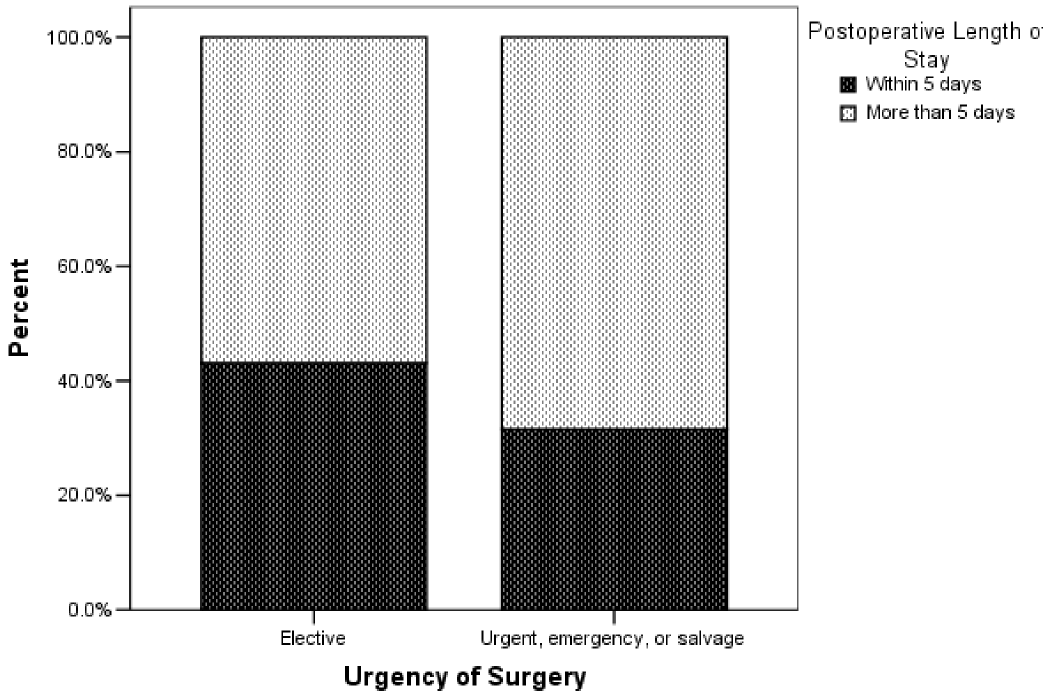


FIGURE 6.2.3.7:

The percentage of patients in each of the discharge groups by urgency of surgery

TIME ON THE WAITING LIST

Waiting list information was not available for 18 patients (1.7%). PLOS was not normally distributed according to the time patients spent on the waiting list as follows; patients not on the waiting list (K-S Z = 4.70, $p < 0.001$), three months or less (K-S Z = 9.12, $p < 0.001$), and more than three months (K-S Z = 2.57, $p < 0.001$).

Table 6.2.3.7 shows the descriptive statistics for time spent on the waiting list and PLOS.

TABLE 6.2.3.7:
POSTOPERATIVE LENGTH OF STAY BY TIME SPENT ON THE WAITING LIST

Time on Waiting List (months)	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Not on list	305	4	45	8.38 (6.05)	6 (5-9)	5	102 (33.4)	203 (66.6)
0-3	636	3	242	8.19 (11.95)	6 (5-8)	5	267 (42.0)	369 (58.0)
>3	84	4	31	7.52 (5.29)	6 (5-8)	5	41 (48.8)	43 (51.2)
Missing							7	11

Hypothesis 1

There was a significant difference between time spent on the waiting list and PLOS (K-W $\chi^2 = 10.44$; df = 2; $p = 0.005$). The level of significance was adjusted to $p = 0.017$ for post hoc comparisons.

Patients who were not placed on the waiting list had significantly longer PLOS than patients who were on the waiting list for three months or less (M-W Z = -2.82, $p = 0.005$), and more than three months (M-W Z = -2.43, $p = 0.015$). Patients who were on the waiting list for three months or less did not differ significantly in PLOS from patients who were on the waiting list for more than three months (M-W Z = -1.10, $p = 0.274$).

Hypothesis 2

There was also a significant association between time on the waiting list and discharge within five days of surgery ($\chi^2 = 9.22$; df = 2; $p = 0.010$) but the strength of the association was low ($\tau = -0.09$; $p = 0.002$). Figure 6.2.3.8 illustrates the association between time spent on the waiting list and discharge within five days.

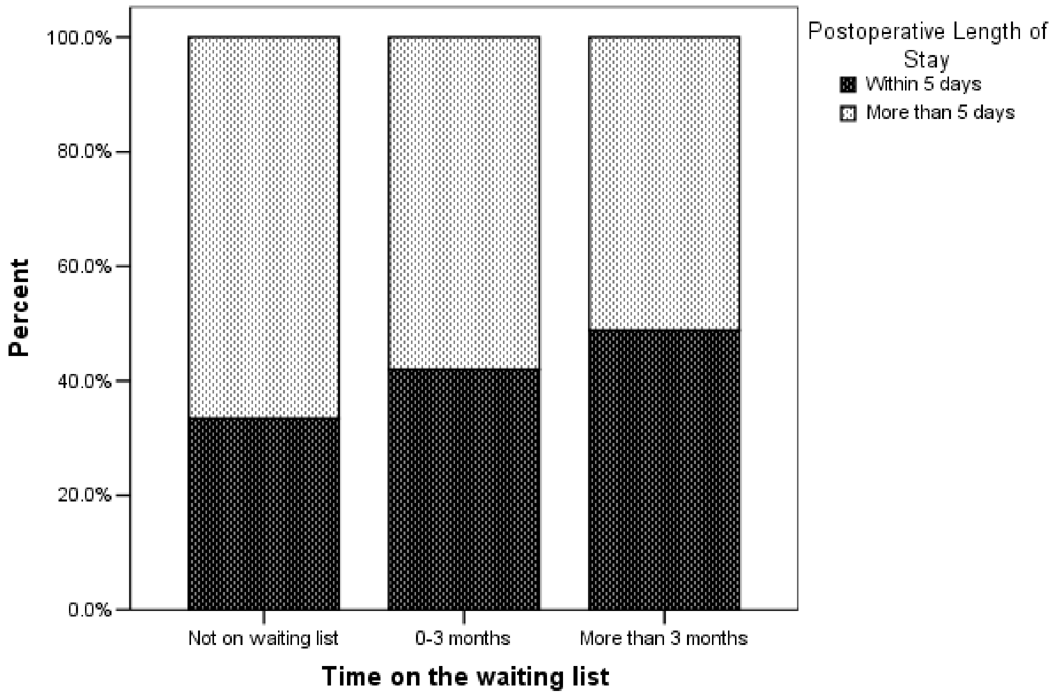


FIGURE 6.2.3.8:

The percentage of patients in each of the discharge groups by time spent on the waiting list

PREOPERATIVE LENGTH OF STAY

PLOS was not normally distributed for patients admitted on the day of or the day before surgery (K-S Z = 8.15, $p < 0.001$), 2-7 days prior to surgery (K-S Z = 3.43, $p < 0.001$), or more than one week before surgery (K-S Z = 4.40, $p < 0.001$).

Table 6.2.3.8 shows the descriptive statistics for preoperative length of stay and PLOS.

TABLE 6.2.3.8:
POSTOPERATIVE LENGTH OF STAY BY PREOPERATIVE LENGTH OF STAY

Preoperative Length of Stay	N	PLOS						
		Min.	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
0-1 days	707	3	95	7.82 (7.41)	6 (5-8)	5	297(42.0)	410 (58.0)
2-7 days	193	4	45	7.52 (4.68)	6 (5-8)	5	77 (39.9)	116 (60.1)
More than 1 week	143	4	242	11.01 (20.78)	7 (5-10)	5	43 (30.1)	100 (69.9)

Hypothesis 1

There were significant differences for preoperative length of stay and PLOS (K-W $\chi^2 = 15.57$; df = 2; $p < 0.001$). The level of significance was adjusted to $p = 0.017$ for post hoc comparisons.

Patients who were admitted 0-1 days prior to surgery were not significantly different in PLOS from patients who were admitted 2-7 days prior to surgery (M-W Z = -0.56, p = 0.575), but had significantly shorter PLOS than those admitted more than one week before surgery (M-W Z = -3.95, p < 0.001). Patients who were admitted 2-7 days prior to surgery also had significantly shorter PLOS than those admitted more than a week before surgery (M-W Z = -2.82, p = 0.005).

Figure 6.2.3.9 illustrates the median PLOS for patients by preoperative length of stay.

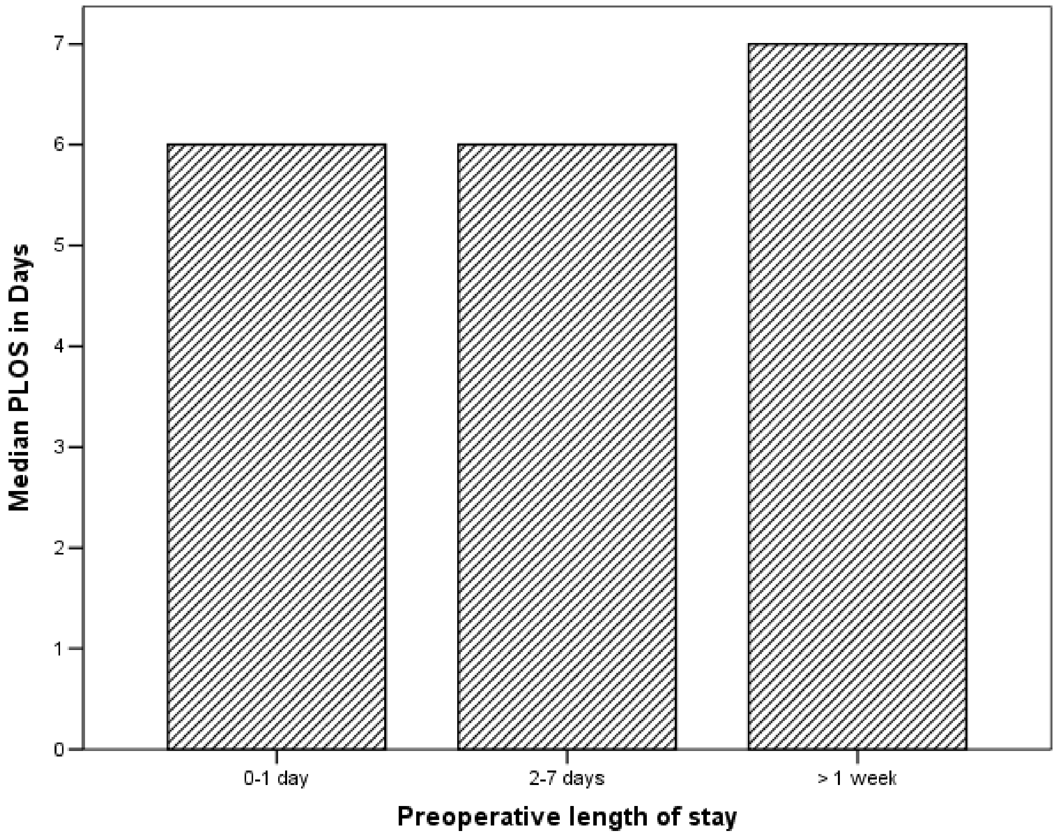


FIGURE 6.2.3.9:

The median postoperative length of stay by preoperative length of stay

Hypothesis 2

There was a significant association between preoperative length of stay and discharge within five days of surgery (χ^2 = 7.07; df = 2; p = 0.029) but the strength of the association was low (τ = 0.07; p = 0.022).

Figure 6.2.3.10 illustrates the association between preoperative length of stay and discharge within five days.

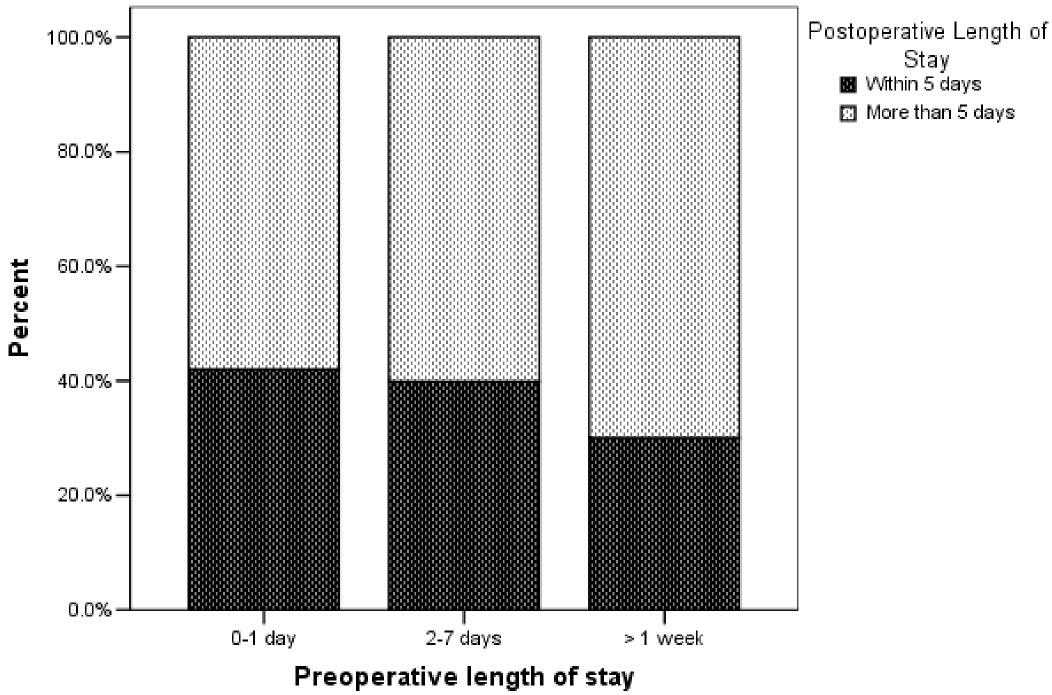


FIGURE 6.2.3.10:

The percentage of patients in each of the discharge groups by preoperative length of stay

Table 6.2.3.9 summarises the univariate test results for severity of illness variables.

TABLE 6.2.3.9:
SUMMARY OF UNIVARIATE TEST RESULTS FOR SEVERITY OF ILLNESS VARIABLES

Variable	Groups	N	% of total	PLOS ≤ 5 days (n)	PLOS > 5 days (n)	Association with PLOS	Association with PLOS ≤ 5 days
Left Main Stem Disease	No	479	45.9	201	278	M-W Z = -1.22, p = 0.222	χ^2 = 2.71, df = 1; p = 0.100
	Yes	215	20.6	76	139		
	Missing	349	33.5	140	209		
Number of Vessels Bypassed	1 or 2	221	21.2	96	125	K-W χ^2 = 1.67, df = 2; p = 0.434	χ^2 = 2.88, df = 2; p = 0.237
	3	507	48.6	206	301		
	4 or 5	295	28.3	107	188		
	Missing	20	1.9	8	12		
Parsonnet Score from hard data		1040	99.7			r_s = 0.24, p < 0.001	M-W Z = -7.03, p < 0.001
Parsonnet Risk Category (Hard)	1%	288	27.6	153	136	K-W χ^2 = 64.63, df = 4; p < 0.001	χ2 = 47.46, df = 4; p < 0.001 τ = 0.23; p < 0.001
	5%	281	26.9	121	162		
	9%	220	21.1	80	139		
	17%	168	16.1	43	124		
	31%	83	8.0	18	64		
	Missing	3	0.3	2	1		
Parsonnet Score (catastrophic states)		1040	99.7			r_s = 0.24, p < 0.001	M-W Z = -7.09; p < 0.001
Parsonnet Risk Category (with catastrophic sates)	1%	289	27.7	153	135	K-W χ^2 = 65.54, df = 4; p < 0.001	χ^2 = 48.62, df = 4; p < 0.001 τ = 0.24; p < 0.001
	5%	283	27.1	120	161		
	9%	219	21.0	81	139		
	17%	167	16.0	43	125		
	31%	82	7.9	18	65		
	Missing	3	0.3	2	1		
EuroSCORE		1024	98.2			r_s = 0.29, p < 0.001	M-W Z = -8.28; p < 0.001
EuroSCORE Risk Category	low	315	30.2	174	141	K-W χ^2 = 72.59, df = 2; p < 0.001	χ^2 = 61.57, df = 2; p < 0.001 τ = 0.26; p < 0.001
	moderate	462	44.3	180	282		
	high	247	23.7	56	191		
	Missing	19	1.8	7	12		

Urgency of Surgery	Elective Non elective Missing	756 285 2	72.5 27.3 0.2	326 90 1	430 195 1	M-W Z = -3.77, $p < 0.001$	$\chi^2 = 11.49$, df = 1; p = 0.001 φ = 0.11; p = 0.001
Time on the Waiting List (months)	0-3 >3 Not on list Missing	636 84 305 18	61.0 8.1 29.4 1.7	267 41 102 7	369 43 203 11	K-W $\chi^2 = 10.44$, df = 2; p = 0.005	$\chi^2 = 9.22$, df = 2; p = 0.010 τ = -0.09; p = 0.002
Preoperative Length of Stay	0-1 days 2-7 days More than 1 week	707 193 143	67.8 18.5 13.7	297 77 43	410 116 100	K-W $\chi^2 = 15.57$, df = 2; $p < 0.001$	$\chi^2 = 7.07$, df = 2; p = 0.029 τ = 0.07; p = 0.022

6.2.4 OPERATIVE AND ORGANISATIONAL VARIABLES

CARDIOPULMONARY BYPASS

Data on surgical approach was not available for 87 patients (8.3%). PLOS was not normally distributed whether CPB was used (K-S Z = 8.07, $p < 0.001$), or not (K-S Z = 4.62, $p < 0.001$).

Table 6.2.4.1 shows the descriptive statistics for CPB and PLOS.

TABLE 6.2.4.1:
POSTOPERATIVE LENGTH OF STAY BY CARDIOPULMONARY BYPASS

CPB	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
No	132	4	242	9.16 (20.86)	6 (5-8)	5	55 (41.7)	77 (58.3)
Yes	824	4	92	8.02 (6.79)	6 (5-8)	5	323 (39.2)	501 (60.8)
Missing	87						39	48

Hypothesis 1

There were no differences in the PLOS of patients who underwent CABG with CPB and those who had off-pump surgery (M-W Z = -0.57, $p = 0.566$).

Hypothesis 2

There was no association between surgical approach and discharge within five days ($\chi^2 = 0.29$; df = 1; $p = 0.590$).

HOSPITAL SITE

PLOS was not normally distributed for either hospital 1 (K-S Z = 8.71, $p < 0.001$), or hospital 2 (K-S Z = 6.25, $p < 0.001$).

Table 6.2.4.2 shows the descriptive statistics for hospital and PLOS.

TABLE 6.2.4.2:
POSTOPERATIVE LENGTH OF STAY BY HOSPITAL

Hospital	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
1	581	3	242	7.98 (11.37)	6 (5-8)	5	247 (42.5)	334 (57.5)
2	462	4	95	8.48 (8.13)	6 (5-8.25)	5	170 (36.8)	292 (63.2)

Hypothesis 1

There were no significant differences in PLOS between patients treated at hospital 1 and hospital 2 (M-W Z = -1.74, $p = 0.082$).

Hypothesis 2

There was no significant association between the hospital of surgery and discharge within five days ($\chi^2 = 3.51$; df = 1; $p = 0.061$).

CONSULTANT SURGEON

PLOS was not normally distributed for the following surgeons; A (K-S Z = 3.19, $p < 0.001$), B (K-S Z = 2.54, $p < 0.001$), C (K-S Z = 3.20, $p < 0.001$), D (K-S Z = 4.19, $p < 0.001$), E (K-S Z = 2.35, $p < 0.001$), G (K-S Z = 1.59, $p = 0.013$), H (K-S Z = 2.72, $p < 0.001$), I (K-S Z = 2.01, $p = 0.001$), J (K-S Z = 4.55, $p < 0.001$), and K (K-S Z = 3.51, $p < 0.001$). Consultant F's patients were not included in the analysis as this was a very small group.

Table 6.2.4.3 shows the descriptive statistics for consultant surgeon and PLOS.

TABLE 6.2.4.3:
POSTOPERATIVE LENGTH OF STAY BY CONSULTANT SURGEON

Consultant Surgeon	N	PLOS						
		Min.	Max	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
A	126	4	44	7.87 (29.88)	6 (5-8)	5	47 (37.3)	79 (62.7)
B	85	4	33	8.88 (6.10)	6 (5-9.5)	5	30 (35.3)	55 (64.7)
C	86	5	81	8.22 (9.61)	6 (5-8)	5	36 (41.9)	50 (58.1)
D	185	4	95	9.36 (10.69)	6 (5-9)	5	60 (32.4)	125 (67.6)
E	117	4	25	6.87 (3.11)	6 (5-8)	5	52 (44.4)	65 (55.6)
*F	5	5	22	9.60 (7.02)	7 (5.5-15)	5	1 (20.0)	4 (80.0)
G	57	5	15	6.91 (2.26)	7 (5-8)	5	19 (33.3)	38 (66.7)
H	74	4	31	7.57 (4.95)	6 (5-7)	5	30 (40.5)	44 (59.5)
I	39	4	44	8.54 (7.45)	6 (5-8)	5	13 (33.3)	26 (66.6)
J	122	4	242	8.31 (21.45)	6 (5-7.5)	5	60 (49.2)	62 (50.8)
K	147	4	55	8.27 (7.40)	6 (5-9)	5	69 (46.9)	78 (53.1)

*Not included in the analysis

Hypothesis 1

There were significant differences in PLOS between the remaining ten consultant surgeons (K-W $\chi^2 = 16.96$; df = 9; $p = 0.049$). However, none of these were significant at the adjusted $p = 0.001$ level.

Hypothesis 2

There was no significant association between consultant surgeon and discharge within five days ($\chi^2 = 15.68$; df = 9; $p = 0.074$).

DAY OF THE WEEK ON WHICH THE FIFTH POSTOPERATIVE DAY OCCURRED

Thursday and Friday were not included in the analysis due to the small number of patients for which the fifth postoperative day occurred on these days. PLOS was not normally distributed for the remaining five days of the week on which the fifth postoperative day occurred; Sunday (K-S Z = 4.76, $p < 0.001$), Monday (K-S Z = 3.91, $p < 0.001$), Tuesday (K-S Z = 4.86, $p < 0.001$), Wednesday (K-S Z = 5.00, $p < 0.001$), and Saturday (K-S Z = 3.93, $p < 0.001$).

Table 6.2.4.4 shows the descriptive statistics for the day of the week on which the fifth postoperative day occurred and PLOS.

TABLE 6.2.4.4:
POSTOPERATIVE LENGTH OF STAY BY DAY OF THE WEEK ON WHICH THE FIFTH POSTOPERATIVE DAY OCCURRED.

Day of the week	N	PLOS						
		Min.	Max.	Mean (s.d)	Median (IQR)	Mode	≤ 5 days n (%)	> 5 days n (%)
Sunday	252	3	95	8.29 (8.36)	6 (5-8)	5	109 (43.3)	143 (56.7)
Monday	187	4	28	7.66 (4.47)	6 (5-8)	5	69 (36.9)	118 (63.1)
Tuesday	227	4	92	8.24 (7.88)	6 (5-8)	5	73 (32.2)	154 (67.8)
Wednesday	169	4	242	9.76 (19.58)	6 (5-8)	5	72 (42.6)	97 (57.4)
Saturday	203	4	43	7.28 (5.05)	6 (5-7)	5	93 (45.8)	110 (54.2)

Hypothesis 1

There were no significant differences in PLOS between the remaining five days of the week (K-W $\chi^2 = 8.57$; df = 4; $p = 0.073$).

Hypothesis 2

There was a significant association between the day of the week on which the fifth postoperative day occurred and discharge within five days ($\chi^2 = 11.00$; df =

4; p = 0.027). The strength of the association was low (Cramér's V = 0.10; p = 0.027).

Figure 6.2.4.1 illustrates the association between the day of the week on which the fifth postoperative day occurred, and discharge within five days.

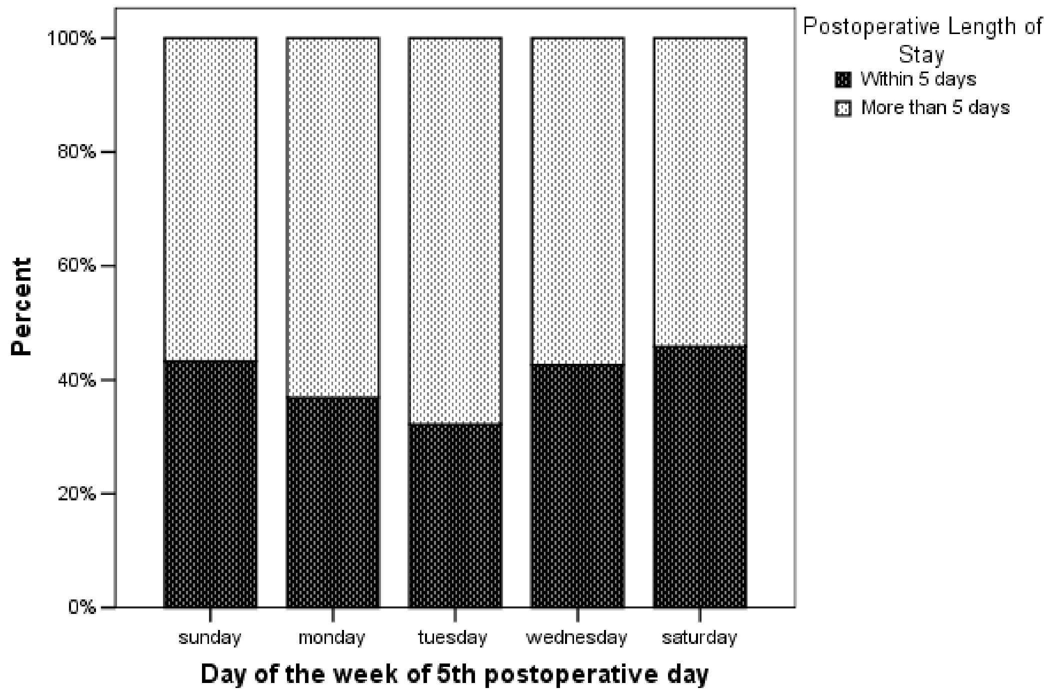


FIGURE 6.2.4.1:

The percentage of patients in each of the discharge groups by the day of the week on which the fifth postoperative day occurred.

Table 6.2.4.5 summarises the results of the univariate tests for operative and organisational variables.

TABLE 6.2.4.5:
SUMMARY OF THE RESULTS OF THE UNIVARIATE TESTS FOR OPERATIVE AND ORGANISATIONAL VARIABLES

Variable	Groups	N	% of total	PLOS ≤ 5 days (n)	PLOS > 5 days (n)	Association with PLOS	Association with PLOS ≤ 5 days
CPB	No	132	12.7	55	77	M-W Z = -0.57, p = 0.566	χ^2 = 0.29, df = 1; p = 0.590
	Yes	824	79.0	323	501		
	Missing	87	8.3	39	48		
Hospital	1	581	55.7	247	334	M-W Z = -1.74, p = 0.082	χ^2 = 3.51, df = 1; p = 0.061
	2	462	44.3	170	292		
Consultant Surgeon	A	126	12.1	47	79	K-W χ^2 = 16.96, df = 9; p = 0.049	χ^2 = 15.68, df = 9; p = 0.074
	B	85	8.1	30	55		
	C	86	8.2	36	50		
	D	185	17.7	60	125		
	E	117	11.2	52	65		
	G	57	5.5	19	38		
	H	74	7.1	30	44		
	I	39	3.7	13	26		
	J	122	11.7	60	62		
	K	147	14.1	69	78		
Day of the week on which the 5th postoperative day occurred	Sunday	252	24.2	109	143	K-W χ^2 = 8.57, df = 4; p = 0.073	χ^2 = 11.00, df = 4; p = 0.027 φ = 0.10; p = 0.027
	Monday	187	17.9	69	118		
	Tuesday	227	21.8	73	154		
	Wednesday	169	16.2	72	97		
	Saturday	203	19.5	93	110		

Table 6.2.4.6 summarises the variables for which the data gave evidence to justify rejecting H_0 at the previously set levels of significance.

TABLE 6.2.4.6:
VARIABLES UNIVARIATELY ASSOCIATED WITH POSTOPERATIVE LENGTH OF STAY/DISCHARGE WITHIN FIVE DAYS

PLOS (Hypothesis 1)		**Discharge within five days of surgery (Hypothesis 2)**	
Null hypothesis rejected	**Null hypothesis accepted**	**Null hypothesis rejected**	**Null hypothesis accepted**
• Age • Age category • Gender • BSA • BSA category • BMI category • Marital status • Living alone • Employment • Deprivation index • Diabetes • Renal disease • Ejection fraction • Dyspnoea • Angina • PVD • Pulmonary disease • Parsonnet score • Parsonnet category • EuroSCORE • EuroSCORE category • Urgency of surgery • Time on the waiting list • Preoperative length of stay	• BMI • Ethic group • Hypertension • Previous MI • Smoking • LMS disease • No. vessels bypassed • CPB • Consultant • Hospital site • Day of fifth day	• Age • Age category • Gender • BSA • BSA category • Marital status • Living alone • employment • Deprivation index • Diabetes • Renal disease • Ejection fraction • Dyspnoea • Angina • PVD • Pulmonary disease • Parsonnet score • Parsonnet category • EuroSCORE • EuroSCORE category • Urgency of surgery • Time on the waiting list • Preoperative length of stay • Day of fifth day	• BMI • BMI category • Ethnic group • Hypertension • Previous MI • Smoking • LMS disease • No. of vessels bypassed • CPB • Hospital • Consultant

Given the assumptions regarding the data and the tests used, where the

Variable	Age category *n* (%)

data gave evidence to justify rejecting the null hypothesis at the previously set 0.05 level of significance, the conclusion was that the data did support the hypothesis that these variables were associated with PLOS or discharge within five postoperative days and were subsequently entered into the respective multivariate analyses.

Where the data did not give evidence to justify rejecting the null hypothesis at the previously set 0.05 level of significance, the conclusion was that these data did not support the hypothesis that those variables were associated with PLOS or discharge within five postoperative days respectively, and were therefore not entered into the multivariate analysis.

Table 6.2.4.7, 6.2.4.8 and 6.2.4.9 show the distribution of variables and missing data by age category, gender and urgency of surgery respectively.

		< 51	51-60	61-70	>70
Gender	**Male**	46 (79.3)	182 (88.3)	305 (82.7)	305 (74.4)
	Female	12 (20.7)	24 (11.7)	64 (17.3)	105 (25.6)
BSA (mean)		1.97	1.98	1.90	1.85
	Missing	0	1	0	1
BMI (mean)		29.20	28.79	28.78	27.05
	Missing	0	1	0	1
Marital Status	**Married/cohab**	42 (79.2)	148 (77.1)	271 (79.0)	275 (73.5)
	Divorced/sep	4 (7.5)	18 (9.4)	27 (7.9)	22 (5.9)
	Single	7 (13.2)	18 (9.4)	17 (5.0)	10 (2.7)
	Widowed	0	8 (4.2)	28 (8.2)	67 (17.9)
	Missing	5 (6.2)	14 (17.3)	26 (32.1)	36 (44.4)
Living alone	**Live alone**	3 (5.8)	30 (16.1)	38 (11.6)	62 (17.0)
	Not alone	49 (94.2)	156 (83.9)	290 (88.4)	303 (83.0)
	Missing	6 (5.4)	20 (17.9)	41 (36.6)	45 (40.2)
Employment	**Working**	19 (61.3)	64 (61.5)	50 (27.3)	11 (5.5)
	Not working	12 (38.7)	40 (38.5)	133 (72.7)	189 (94.5)
	Missing	27 (5.1)	102 (19.4)	186 (35.4)	210 (40.0)
ID 2004 (mean)		27.4	22.9	22.6	20.4
	Missing	3 (7.9)	2 (5.3)	12 (31.6)	21 (55.3)
Diabetes	**Diabetic**	15 (26.3)	60 (29.1)	127 (34.4)	95 (23.2)
	Not diabetic	42 (73.7)	146 (70.9)	242 (65.6)	314 (76.8)
	Missing	1	0	0	1
Renal Disease	**Yes**	3 (5.2)	4 (2.0)	12 (3.3)	13 (3.2)
	No	55 (94.8)	201 (98.0)	356 (96.7)	394 (96.8)
	Missing	0	1	1	3
EF	**Good**	37 (63.8)	139 (67.8)	223 (60.4)	231 (56.5)
	Fair	16 (27.6)	53 (25.9)	117 (31.7)	143 (35.0)
	Poor	5 (8.6)	13 (6.3)	29 (7.9)	35 (8.6)
	Missing	0	1	0	1
Dyspnoea	**NYHA 1**	19 (45.2)	49 (35.5)	105 (39.8)	88 (29.6)
	NYHA 2	19 (45.2)	56 (40.6)	109 (41.3)	148 (49.8)
	NYHA 3&4	4 (9.5)	33 (23.9)	50 (18.9)	61 (20.5)
	Missing	16 (5.3)	68 (22.5)	105 (34.8)	113 (37.4)
Angina	**CCS 0&1**	13 (31.0)	33 (23.9)	69 (25.9)	50 (16.9)
	CCS 2	13 (31.0)	62 (44.9)	93 (35.0)	108 (36.5)
	CCS 3&4	16 (38.0)	43 (31.2)	104 (39.1)	138 (46.6)
	Missing	16 (5.3)	68 (22.6)	103 (34.2)	114 (37.9)
PVD	**Yes**	7 (12.1)	20 (9.8)	60 (16.3)	68 (16.6)
	No	51 (87.9)	185 (90.2)	309 (83.7)	341 (83.4)
	Missing	0	1	0	1
Parsonnet Score (mean)		4.74	4.50	5.84	15.50
	Missing	0	1	1	1
EuroSCORE (mean)		2.17	1.53	3.68	5.82
	Missing	0	6	6	7
Urgency	**Elective**	34 (58.6)	158 (77.1)	279 (75.6)	285 (69.7)
	Non elective	24 (41.4)	47 (22.9)	90 (24.4)	124 (30.3)
	Missing	0	1	0	1
Waiting list	**0-3 months**	26 (45.6)	133 (65.2)	233 (64.0)	244 (61.0)
	> 3 months	6 (10.5)	18 (8.8)	30 (8.2)	30 (7.5)
	Not on list	25 (43.9)	53 (26.0)	101 (27.7)	126 (31.5)
	Missing	1 (5.56)	2 (11.1)	5 (27.8)	10 (55.6)
Pre-op stay	**0-1 day**	37 (63.8)	145 (70.4)	248 (67.2)	277 (67.6)
	2-7 days	12 (20.7)	37 (18.0)	73 (19.8)	71 (17.3)
	> 7 days	9 (15.5)	24 (11.7)	48 (13.0)	62 (15.1)

TABLE 6.2.4.7:
DISTRIBTION OF VARIABLES AND MISSING DATA BY AGE CATEGORY
TABLE 6.2.4.8:

DISTRIBTION OF VARIABLES AND MISSING DATA BY GENDER

Variable		Gender *n* (%)	
		Male	**Female**
Age in years (mean)		66.2	68.8
BSA (mean)		1.94	1.74
	Missing	2	0
BMI (mean)		28.1	28.0
	Missing	2	0
Marital Status	**Married/cohab**	622 (80.4)	114 (60.6)
	Divorced/sep	60 (7.8)	11 (5.9)
	Single	45 (5.8)	7 (3.7)
	Widowed	47 (6.1)	56 (29.8)
	Missing	64 (79.0)	17 (21.0)
Living alone	**Live alone**	89 (11.8)	44 (24.9)
	Not alone	665 (88.2)	133 (75.1)
	Missing	84 (75.0)	28 (25.0)
Employment	**Working**	134 (32.1)	10 (9.9)
	Not working	283 (67.9)	91 (90.1)
	Missing	421 (80.2)	104 (19.8)
ID 2004 (mean)		22.0	22.2
	Missing	23 (60.5)	15 (39.50)
Diabetes	**Diabetic**	236 (28.2)	61 (29.8)
	Not diabetic	600 (71.8)	144 (70.2)
	Missing	2	0
Renal Disease	**Yes**	24 (2.9)	8 (3.9)
	No	810 (97.1)	196 (96.1)
	Missing	4	1
EF	**Good**	486 (58.1)	144 (70.2)
	Fair	276 (33.0)	53 (25.9)
	Poor	74 (8.9)	8 (3.9)
	Missing	2	0
Dyspnoea	**NYHA 1**	220 (36.9)	41 (28.3)
	NYHA 2	261 (43.8)	71 (49.0)
	NYHA 3&4	115 (19.3)	33 (22.8)
	Missing	242 (80.1)	60 (19.9)
Angina	**CCS 0&1**	146 (24.5)	19 (13.1)
	CCS 2	218 (36.5)	58 (40.0)
	CCS 3&4	233 (39.0)	68 (46.9)
	Missing	241 (80.1)	60 (19.9)
PVD	**Yes**	130 (16.6)	25 (12.2)
	No	706 (84.4)	180 (87.8)
	Missing	2	0
Parsonnet Score (mean)		8.80	11.42
	Missing	3	0
EuroSCORE (mean)		3.76	5.06
	Missing	15 (78.9)	4 (21.2)
Urgency	**Elective**	607 (72.6)	149 (72.7)
	Non elective	229 (27.4)	56 (27.3)
	Missing	2	0
Waiting list	**0-3 months**	516 (62.5)	120 (60.0)
	> 3 months	65 (7.9)	19 (9.5)
	Not on list	244 (29.6)	61 (30.5)
	Missing	13 (72.2)	5 (27.8)
Pre-op stay	**0-1 day**	573 (68.4)	134 (65.4)
	2-7 days	152 (18.1)	41 (20.0)
	> 7 days	113 (13.5)	30 (14.6)

TABLE 6.2.4.9:
DISTRIBTION OF VARIABLES AND MISSING DATA BY URGENCY OF SURGERY

Variable		Urgency of Surgery *n* (%)		
		Elective	**Non-Elective**	**Missing**
Age (mean)		66.5	67.2	68.0
Gender	**Male**	607 (80.3)	229 (80.4)	2
	Female	149 (19.7)	56 (19.6)	0
BSA (mean)		191	1.88	X
	Missing	0	0	2
BMI (mean)		28.55	26.92	X
	Missing	0	0	2
Marital Status	**Married/cohab**	539 (75.6)	195 (78.9)	2
	Divorced/sep	53 (7.4)	18 (7.3)	0
	Single	40 (5.6)	12 (4.9)	0
	Widowed	81 (11.4)	22 (8.9)	0
	Missing	43 (53.1)	38 (46.9)	0
Living alone	**Live alone**	101 (14.7)	32 (13.3)	0
	Not alone	587 (85.3)	209 (86.7)	2
	Missing	68 (60.7)	44 (39.3)	0
Employment	**Working**	107 (27.6)	37 (28.7)	0
	Not working	281 (72.4)	92 (71.3)	1
	Missing	368 (70.1)	156 (29.7)	1 (0.2)
ID 2004 (mean)		21.38	23.79	31.06
	Missing	28 (73.7)	10 (26.3)	0
Diabetes	**Diabetic**	200 (26.5)	97 (34.0)	0
	Not diabetic	556 (73.5)	188 (66.0)	0
	Missing	0	0	2
Renal Disease	**Yes**	19 (2.5)	13 (4.6)	0
	No	735 (97.5)	271 (95.4)	0
	Missing	2 (40.0)	1 (20.0)	2 (40.0)
EF	**Good**	504 (66.7)	126 (44.2)	0
	Fair	205 (27.1)	124 (43.5)	0
	Poor	47 (6.2)	35 (12.3)	0
	Missing	0	0	2
Dyspnoea	**NYHA 1**	197 (36.7)	64 (31.4)	0
	NYHA 2	239 (44.5)	93 (45.6)	0
	NYHA 3&4	101 (18.8)	47 (23.0)	0
	Missing	219 (72.5)	81 (26.8)	2 (0.7)
Angina	**CCS 0&1**	140 (26.0)	25 (12.3)	0
	CCS 2	224 (41.6)	52 (25.5)	0
	CCS 3&4	174 (32.3)	127 (62.3)	0
	Missing	218 (72.4)	81 (26.9)	2 (0.7)
PVD	**Yes**	81 (10.7)	74 (26.0)	0
	No	675 (89.3)	211 (74.0)	0
	Missing	0	0	2
Parsonnet Score (mean)		8.72	10.88	X
	Missing	0	1	2
EuroSCORE (mean)		3.32	5.84	
	Missing	13 (68.4)	4 (21.1)	2 (10.5)
Waiting list	**0-3 months**	589 (79.7)	46 (16.2)	1
	> 3 months	77 (10.4)	6 (2.1)	1
	Not on list	73 (9.9)	232 (81.7)	0
	Missing	17 (94.4)	1 (5.6)	0
Pre-op stay	**0-1 day**	631 (83.5)	74 (26.0)	2
	2-7 days	96 (12.7)	97 (34.0)	0
	> 7 days	29 (3.8)	114 (40.0)	0

6.3 MULTIVARIATE ANALYSES

This section presents the results of the tests of hypotheses 3 and 4 which state that; PLOS and discharge within five days of first time isolated CABG can be predicted from one or more of the preoperative variables identified in Phase I of the study.

6.3.1 PREDICTING POSTOPERATIVE LENGTH OF STAY

A multivariable one-way ANOVA was performed on 941 patients with a PLOS of 12 days or less as the removal of outliers resulted in a more symmetric distribution. A sample size of 760 patients was required for the modelling of PLOS from 19 variables.

Model 1

Model 1 was developed from the main effects of 19 variables found to be associated with PLOS by univariate analysis (Table 6.3.1.1). Continuous levels of measurement were included where possible.

TABLE 6.3.1.1:
VARIABLES INCLUDED IN MODEL 1

Variables included in Model 1
• Age • Gender • BSA • marital status • living alone • employment status • index of deprivation • diabetes (three classifications) • renal function • ejection fraction • dyspnoea classification • angina classification • PVD • pulmonary disease • Parsonnet score (from hard data) • EuroSCORE • urgency of surgery • time on the waiting list • preoperative length of stay

There were no significant interactions between these variables. The VIF statistics indicated that there was not a problem with multi-collinearity between the variables. All VIF statistics were less than ten and the average was 1.92.

Based on complete case analysis the model was developed from 833 patients (88.5%). The analysis was therefore sufficiently powered with 43.8 cases per variable. Only the following variables were significant:

- Age (F = 37.40, df = 1; $p < 0.001$)
- Marital status (F = 4.58, df = 3; p = 0.003)
- Index of deprivation (F = 13.20, df = 1; p < 001).
- Renal function (F = 5.82, df = 1; p = 0.016),
- Ejection fraction (F = 4.25, df = 2; p = 0.015)
- PVD (F = 4.55, df = 1; p = 0.033)

However, the assumption of homogeneity of variance was not met (F = 1.693, df 1 = 799, df 2 = 31; p = 0.011), and the proportion of the variance of PLOS accounted for by the model was low $R^2 = 0.115$ (adjusted $R^2 = 0.105$). The lack of fit test was significant (F = 8.81, df = 818; p = 0.048). The residuals were not normally distributed (KS-Z = 3.12, $p < 0.001$).

The multi-collinearity statistics for the variables entered into model 1, together with the between-subjects effects and parameter estimates for the variables in the final model are included in appendix 4. Entering the values into the regression equation gives the equation for PLOS after CABG (Figure 6.3.1.1).

FIGURE 6.3.1.1:

Equation for postoperative length of stay – Model 1

PLOS = 5.120 + (-1.035 x renal function=1) + (-0.737 x marital status=1 or -0.525 x marital status=2 or -0.857 x marital status=3) + (0.016 x index of deprivation) + (0.41 x age) + (0.461 x ejection fraction=1 or 0.336 x ejection fraction=2) + (-0.373 x PVD=0).

The equation was used to calculate predicted PLOS for patients in Phase II. Validation of the model showed that the distributions of predicted PLOS and actual PLOS for this cohort did not differ (WSR-Z = 0.043; p = 0.966).

Model 2

Model 2 was developed from the main effects of the same 19 variables as model 1 but categorical levels of measurement were substituted for age, BSA, Parsonnet score (from hard data), and EuroSCORE. There were no significant interactions between these variables. The VIF statistics indicated that there was not a problem with multi-collinearity between the variables. All VIF statistics were less than ten and the average was 1.73.

Based on complete case analysis, the model was developed from 831 patients (88.3%). The analysis was therefore sufficiently powered with 43.7 cases per variable. Only the following variables were significant:

- age category (F = 4.07, df = 3; p < 0.007)
- marital status (F = 3.85, df = 3; p = 0.009)
- index of deprivation (F = 11.82, df = 1; p < 001).
- diabetes (F = 4.53, df = 2; p = 0.011)
- ejection fraction (F = 3.23, df = 2; p = 0.040)
- Parsonnet risk category (F = 5.76, df = 4; p < 0.001)

However, the assumption of homogeneity of variance was not met (F = 1.392, df 1 = 671, df 2 = 161; p = 0.003), and the proportion of the variance of PLOS accounted for by the model was low R^2 = 0.133 (adjusted R^2 = 0.117). The lack of fit test was significant (F = 5.81, df = 809; p = 0.006). The residuals were not normally distributed (KS-Z = 3.07, p < 0.001).

The multi-collinearity statistics for the variables entered into model 2, together with the between-subjects effects and parameter estimates for the variables in the final model are included in appendix 4. Entering the values into the regression equation gives the equation PLOS after CABG (Figure

6.3.1.2).

FIGURE 6.3.1.2:

Equation for postoperative length of stay – Model 2

PLOS = 7.904 + (-0.504 x age=1 or -0.297 x age=2 or 0.183 x age=3) + (0.334 x ejection fraction=1 or 0.348 x ejection fraction=2) + (-1.004 x Parsonnet=1 or -1.182 x Parsonnet=2 or -0.882 x Parsonnet=3 or -0.126 x Parsonnet=4) + (-0.646 x marital status=1 or -0.338 x marital status=2 or -0.719 x marital status) + (0.015 x index of deprivation) + (-0.686 x diabetes=1 or -0.572 x diabetes=2).

The equation was used to calculate predicted PLOS for patients in Phase II. Validation of the model showed that the distributions of predicted PLOS and actual PLOS for this cohort did not differ (WSR-Z = 1.736; p = 0.083).

6.3.2 PREDICTING MEMBERSHIP OF THE FIVE-DAY DISCHARGE CATEGORY

A sample size of 190 patients discharged within five days and 190 patients discharged after five days was required for the modelling of discharge within five days from 19 variables.

Model 3

Model 3 was developed from the analysis of 19 variables, found to be associated with discharge within five days by univariate analysis, using binary logistic regression (Table 6.3.2.1). Although renal failure was associated with discharge within five days by univariate analysis, this variable was omitted from the analysis due to the small number of patients with renal failure and the inability therefore to estimate coefficients for this category. Continuous levels of measurement were included where possible. All VIF statistics were less than ten and the average VIF statistic was 1.94.

TABLE 6.3.2.1:
VARIABLES INCLUDED IN MODEL 3

Variables included in Model 3
• Age • Gender • BSA • marital status • living alone • employment status • index of deprivation • diabetes (three classifications) • ejection fraction • dyspnoea classification • angina classification • PVD • pulmonary disease • Parsonnet score (from hard data) • EuroSCORE • urgency of surgery • time on the waiting list • preoperative length of stay • day of 5th postoperative day

Based on complete case analysis, a total of 313 cases were included in the model (30.0%). This was a substantial decrease in the sample size with 730 cases missing (70.0%) and resulted in the analysis being underpowered based on the sample size calculations.

Tabulations of missing data are presented in appendix 4 and show that data missing was concentrated in the following variables: dyspnoea, angina, marital status, living alone and employment. Closer inspection of the missing data showed that this was not random but concentrated in patients who underwent non-elective surgery. This is not surprising since less time is available for preoperative assessment in emergency situations but may have resulted in a sample bias towards lower risk elective patients.

The first step of the model included all 19 variables and gave the best sensitivity (55.4%), specificity (83.3%) and the overall percentage correct (72.5%). A non significant Hosmer and Lemeshow goodness-of-fit test indicated that the model did adequately fit the data ($\chi 2 = 13.86$; df = 8; p = 0.085). The Nagelkerke statistic indicated that the variation that was explained by the model was low at 0.264 indicating that the model accounted for approximately 26% of the variance. The performance of the model was also poor with a c statistic of 0.60.

Non significant likelihood ratio tests indicated that removing the following variables may have resulted in a more parsimonious model: PVD, time on the waiting list, pulmonary disease, BSA, diabetes, living alone, age, employment, Parsonnet score, day of fifth postoperative day and ejection fraction. However, this reduced the sensitivity and overall classifications correct to 42.1% and 68.4% respectively, although specificity improved to 84.9%. As the amount of variability explained by this reduced model also decreased to 15.6%, all the variables were retained in the final model.

The residuals were not normally distributed (KS-Z = 4.38, $p < 0.001$), and the proportion of standardised residuals outside the range -1.96 to 1.96 was 4.8%. No influential points were identified.

Applying the model values into the logistic regression equation gave the equation to predict the probability of discharge within five days of CABG (Figure 6.3.2.1).

FIGURE 6.3.2.1:

Equation for the probability for discharge with 5 days – Model 3

P(discharge within 5 days of CABG) = $1/\ 1+e^{-z}$

Z = -1.785 + (-0.027 x age) + (0.534 x gender=1) + (0.631 x BSA) + (-0.314 x diabetes=2) + (-0.511 x diabetes=3) + (-0.111 x EF=2) + (0.721 x EF=3) +(-0.440 x dyspnoea=2) + (-0.834 x dyspnoea=3) + (1.133 x angina=2) + (0.880 x angina=3) + (-0.082 x PVD=0) + (-0.298 x pulmonary=0) + (0.063 x Parsonnet score) + (-0.257 x EuroSCORE) + (1.113 x urgency=1) + (0.545 x waiting list=0) + (-0.009 x waiting list=1) + (0.645 x preoperative stay=2) + (1.393 x preoperative stay=3) + (-0.360 x 5th day=1) + (-0.060 x 5th day=2) + (-0.884 x 5th day=3) + (0.049 x 5th day=4) + (1.630 x marital status=1) + (1.498 x marital status=2) + (0.347 x marital status=3) + (-0.731 x living alone=0) + (-0.474 x employment=1) + (-0.008 x deprivation index)

The equation was used to predict discharge within five days for patients in Phase II. Validation of the model showed that there was a difference between predicted discharge and actual discharge within five days for this cohort ($\chi^2 = 40.19$; $p < 0.001$). A c-statistic of 0.57 showed the model performance was poor.

Table 6.3.2.2 shows a comparison of the final model performance with models developed with 0.4 and 0.3 cut-off points. These models were re-run using all the data for which the variables included in them were complete, thus increasing the number of complete cases analysed in these models. The table illustrates the improved sensitivity of the models with lower cut-off points but the greater percentage of false positive predictions.

TABLE 6.3.2.2:
COMPARISON OF PERFORMANCE OF MODELS DEVELOPED WITH 0.5, 0.4 AND 0.3 CUT-OFF POINTS

	Cut-off				
	0.5 (model 3)	**0.4 (model 5)**	**0.4 re-rerun (model 6)**	**0.3 (model 7)**	**0.3 re-run (model 8)**
Sensitivity (%)	55.4	71.7	69.9	85.1	84.6
Specificity (%)	83.3	69.8	70.3	47.4	39.9
False Positive (%)	32.3	40.3	30.1	49.5	61.8
False Negative (%)	25.2	20.7	29.7	16.5	14.2
Overall (%)	72.5	70.3	70.1	62.0	56.1
R^2	0.264	0.259	0.248	0.187	0.142
No. Cases	313	313	318	313	738
No. Variables	19	16	16	7	7
Hosmer-Lemeshow	$\chi^2 = 13.86$ df = 8 P = 0.085	$\chi^2 = 15.20$ df = 8 P = 0.055	$\chi^2 = 5.893$ df = 8 P = 0.659	$\chi^2 = 8.274$ df = 8 P = 0.407	$\chi^2 = 5.873$ df = 8 P = 0.661
Proportion of Standardised residuals outside range -1.96 to 1.96 (%)	4.8	10.2	9.7	10.5	0.8
No. influential points	0	0	0	0	0
C statistic	0.60	0.63	0.63	0.61	0.61
Phase II Validation **McNemer Test**	$\chi^2 = 40.19$ P < 0.001	$\chi^2 = 8.44$ P = 0.004	$\chi^2 = 10.10$ P < 0.001	$\chi^2 = 104.18$ P < 0.001	$\chi^2 = 147.18$ P < 0.001
C statistic	0.57	0.50	0.50	0.50	0.50

Model 4

Model 4 was developed from the same 19 variables as model 3 but categorical levels of measurement were substituted for age, BSA, Parsonnet score (from hard data), and EuroSCORE. All VIF statistics were less than ten and the average VIF statistic was 1.73.

A total of 313 cases were included in the model (30.0%). Therefore 730 cases were missing (70.0%) and resulted in the analysis being underpowered. Again, the first step of the model included all 19 variables and gave the best sensitivity (56.2%), specificity (79.7%) and the overall percentage correct (70.6%). A non significant Hosmer and Lemeshow goodness-of-fit test indicated that the model adequately fitted the data ($\chi2 = 12.45$; $df = 8$; $p = 0.132$). The Nagelkerke statistic indicated that the variation that was explained by the model was medium at 0.313, accounting for approximately 31% of the variation. However, the performance of the model was poor with a c-statistic of 0.62.

Non significant likelihood ratio tests indicated that removing the following variables may have resulted in a more parsimonious model: age category, gender, time on the waiting list, index of deprivation, PVD, diabetes, pulmonary disease, employment and living alone. However, this reduced the sensitivity and overall classifications correct to 54.5% and 70.3% respectively, although specificity improved to 80.2%. As the amount of variability explained by this reduced model also decreased to 26.6%, all the variables were retained in the final model. The residuals were not normally distributed (KS-Z = 3.13, $p < 0.001$) and the proportion of standardised residuals outside the range -1.96 to 1.96 was 10.2%. No influential points were identified.

Applying the model values into the logistic regression equation gave the equation to predict the probability of discharge within five days of CABG (Figure 6.3.2.2).

FIGURE 6.3.2.2:

Equation for the probability for discharge with 5 days – Model 4

$$P(\text{discharge within 5 days of CABG}) = 1/ 1+e^{-z}$$

Z = -2.603 + (-0.320 x age category=2) + (-0.613 x age category=3) + (-0.564 x age category=4) + (0.201 x gender=1) + (1.405 x BSA category=2) + (1.075 x BSA category=3) + (-0.477 x diabetes=2) + (-0.120 x diabetes=3) + (-0.140 x EF=2) + (0.753 x EF=3) +(-0.497 x dyspnoea=2) + (-1.106 x dyspnoea=3) + (1.244 x angina=2) + (1.023 x angina=3) + (-0.301 x PVD=0) + (-0.479 x pulmonary=0) + (0.207 x Parsonnet risk=2) + (0.321 x Parsonnet risk=3) + (-0.212 x Parsonnet risk=4) + (1.616 x Parsonnet risk=5) + (-0.717 x EuroSCORE risk=2) + (-2.081 x EuroSCORE risk=3) + (1.040 x urgency=1) + (0.520 x waiting list=0) + (0.178 x waiting list=1) + (0.667 x preoperative stay=2) + (1.396 x preoperative stay=3) + (-0.401 x 5^{th} day=1) + (-0.094 x 5^{th} day=2) + (-1.082 x 5^{th} day=3) + (0.002 x 5^{th} day=4) + (1.955 x marital status=1) + (1.694 x marital status=2) + (0.764 x marital status=3) + (-0.719 x living alone=0) + (-0.498 x employment=1) + (-0.006 x deprivation index)

The equation was used to predict discharge within five days for patients in Phase II. Validation of the model again showed a difference between predicted discharge and actual discharge within five days for this cohort ($\chi^2 = 6.34$; $p = 0.012$). A c-statistic of 0.55 showed the model performance was poor.

Table 6.3.2.3 shows a comparison of the final model performance with models developed with 0.4 and 0.3 cut-off points. Again, the improved sensitivity of the models with lower cut-off points increased the percentage of false positive predictions.

The odds ratios and 95% confidence intervals, Likelihood ratio tests, ROC curves and c statistics for all the models developed in section 6.3.2 are presented in appendix 4 together with the multi-collinearity statistics for the variables entered into these models.

TABLE 6.3.2.3:
COMPARISON OF PERFORMANCE OF MODELS DEVELOPED WITH 0.5, 0.4 AND 0.3 CUT-OFF POINTS

	Cut-off			
	0.5 (model 4)	**0.4 (model 9)**	**0.4 re-rerun (model 10)**	**0.3 (model 11)**
Sensitivity (%)	56.2	69.4	70.2	85.1
Specificity (%)	79.7	67.2	56.5	51.6
False Positive (%)	36.4	42.9	43.5	47.4
False Negative (%)	25.7	22.3	29.8	15.4
Overall (%)	70.6	68.1	62.0	64.5
R^2	0.313	0.239	0.150	0.313
No. Cases	313	313	682	313
No. Variables	19	8	8	19
Hosmer-Lemeshow	$\chi^2 = 12.45$ df = 8 P = 0.132	$\chi^2 = 8.754$ df = 8 P = 0.363	$X^2 = 9.360$ df = 8 P = 0.313	$\chi^2 = 12.445$ df = 8 P = 0.132
Proportion of Standardised residuals outside range -1.96 to 1.96 (%)	10.2	9.6	1.8	9.6
No. influential points	0	0	0	0
C statistic	0.62	0.63	0.63	0.62
Phase II Validation **McNemer Test**	$\chi^2 = 6.34$ P = 0.012	$\chi^2 = 11.06$ P = 0.001	$\chi^2 = 31.27$ P < 0.001	$\chi^2 = 85.20$ P < 0.001
C statistic	0.55	0.50	0.50	0.54

6.4 PSYCHOLOGICAL VARIABLES

6.4.1 PRECEIVED STRESS SCALE

The PSS was scored for 67 patients in phase II of the study (13.3%). As 229 patients attended preadmission clinic during the data collection period and would have been eligible to complete the questionnaires this equated to a response rate of 29.3%. The scores ranged from 0-30 (mean 15.51, sd 7.83) and were normally distributed (K-S Z = 0.607, p = 0.855). Three patients completed the PSS more than 8 weeks before surgery.

<u>Hypothesis 1</u>

There was no significant association between PSS score and PLOS (r_S = 0.08; n = 67; p = 0.499).

Hypothesis 2

The mean score of patients discharged within and after five days of surgery were 15.48 (sd 6.68) and 15.53 (sd 8.69) respectively. The scores were normally distributed for both those discharged within five days (K-S Z = 0.91, p = 0.381), and those discharged after five days (K-S Z = 0.62, p = 0.838).

There was no significant difference in the scores of patients discharged within five days and those who had a longer PLOS (t = 0.023, df = 64.99; p = 0.982), equal variances not assumed (F = 5.05; p = 0.028).

Table 6.4.1.1 illustrates the descriptive statistics for PSS score and selected categorical variables.

TABLE 6.4.1.1
DESCRIPTIVE STATISTICS FOR PERCEIVED STRESS SCALE SCORE.

Variable		N	%	Mean	SD	Med.	Min.	Max.	Association With PSS
Age	<51	8	15.4	16.75	6.34	16.5	6	26	
	51-60	17	16.2	17.88	7.68	17.0	7	30	R_2 = -0.11, p = 0.34
	61-70	21	12.8	15.10	9.45	15.0	0	30	
	>70	21	11.5	13.52	6.46	14.0	3	27	
Gender	Male	58	14.2	15.50	8.22	15.0	0	30	t=-0.20, df = 65; p=0.98
	Female	9	9.5	15.55	4.90	14.0	10	23	
BSA	<1.70	6	7.7	19.17	8.28	19.5	10	27	
	1.70-1.89	22	12.5	15.82	7.14	16.0	3	30	f=0.55, df=2; p=0.58
	>1.89	32	14.4	15.34	8.84	15.5	0	30	
BMI	<25	19	13.5	15.21	8.18	16.0	3	30	
	25-30	17	8.8	14.00	7.68	13.0	0	26	f=0..55, df=2; p=0.31
	>30	24	16.9	17.79	8.35	17.5	4	30	
Diabetes	Not diabetic	45	14.3	15.09	8.24	14.0	0	30	
	Diet or oral therapy	10	9.8	16.20	8.34	16.0	5	30	f=0.1.99, df=2; p=0.15
	Insulin therapy	5	7.8	22.60	3.21	23.0	18	26	
EF	Poor	2	6.9	17.50	7.68	17.5	5	30	
	Fair	15	10.4	13.80	7.84	14.0	3	26	f=0.67, df=2; p=0.52
	Good	43	14.0	16.56	7.94	16.0	0	30	
Renal failure	No	56	12.2	15.41	8.15	15.0	0	30	t=-1.77, df=58; p=0.08
	Yes	4	20.0	22.75	4.03	23.0	18	27	
Dyspnoea	NYHA 1	26	19.0	14.73	8.93	16.0	0	30	
	NYHA 2	25	10.8	15.56	6.13	14.0	3	27	f=1.59, df=2; p=0.21
	NYHA 3&4	9	8.4	20.22	10.02	25.0	4	30	
Angina	CCS 0&1	12	18.2	14.00	8.98	12.0	3	30	
	CCS 2	32	15.5	15.81	7.69	15.5	0	30	f=0.63, df=2; p=0.54
	CCS 3&4	16	7.8	17.50	5.58	16.5	4	30	
PVD	No	57	13.7	15.79	8.20	16.0	0	30	t=-0.46, df=58; p=0.65
	Yes	3	4.6	18.00	8.00	18.0	10	26	
Pulmonary Disease	No	54	13.3	15.96	8.25	16.5	0	30	t=-0.18, df=58; p=0.86
	Yes	6	7.9	15.33	7.74	14.0	7	30	

Variable		N	%	Mean	SD	Med.	Min.	Max.	Association With PSS
Parsonnet risk	1%	20	13.4	15.30	8.98	15.0	0	30	
	5%	16	12.5	18.00	8.41	20.5	3	27	
	9%	8	9.5	16.38	8.07	16.0	3	30	f=0.45, df=4;
	17%	13	18.6	14.08	6.40	14.0	4	25	p=0.77
	31%	3	6.8	15.33	11.06	14.0	5	27	
EuroSCORE	0-2	32	16.9	16.40	8.59	16.5	0	30	
	3-5	22	12.6	16.36	7.76	16.5	3	30	f=0.97, df=2;
	>6	6	5.5	11.50	6.71	11.0	5	23	p=0.38
Marital	Married/cohab	55	15.1	14.93	8.18	14.0	0	30	
Status	Divorced/sep	4	19.0	15.00	2.16	15.5	12	17	f=1.20, df=3;
	Single	5	13.5	21.20	6.72	24.0	13	27	p=0.32
	Widowed	2	3.9	20.00	1.41	20.0	19	21	
Living alone	No	59	14.4	15.22	8.04	14.0	0	30	t=-1.02, df=64;
	Yes	7	12.3	18.43	6.05	16.0	12	27	p=0.31
Employment	Working	15	15.8	14.20	7.86	13.0	3	27	t=0.47, df=36;
	Not working	25	12.4	14.00	6.74	13.0	4	30	p=0.64

6.4.2 MULTIDIMENSIONAL HEALTH LOCUS OF CONTROL - INTERNAL

The internal items of MHLC were scored for 68 patients (13.5%), a response rate of 29.7% of eligible patients. The scores ranged from 14-36 (mean 27.60, sd 4.90) and were not normally distributed (K-S Z = 1.426, p = 0.034).

Hypothesis 1

There was no significant association between PSS score and PLOS (r_S = 0.11; n = 68; p = 0.376).

Hypothesis 2

The mean scores of patients discharged within and after five days of surgery were 28.82 (sd 5.50) and 28.22 (sd 4.35) respectively. The scores were normally distributed for both those discharged within five days (K-S Z = 0.830, p = 0.497), and those discharged after five days (K-S Z = 1.147, p = 0.144).

There was no significant difference in the scores of patients discharged within five days and those who had a longer PLOS (t = 1.165, df = 66; p = 0.248), equal variances assumed (F = 1.71; p = 0.195).

6.4.3 MULTIDIMENSIONAL HEALTH LOCUS OF CONTROL - CHANCE

The chance items of MHLC were scored for 67 patients (13.3%), a response rate of 29.3% of eligible patients. The scores ranged from 6-34 (mean 18.06, sd 6.15) and were normally distributed (K-S Z = 0.540, p = 0.932).

Hypothesis 1

There was no significant association between PSS score and PLOS (r_s = 0.14; n = 67; p = 0.256).

Hypothesis 2

The mean scores of patients discharged within and after five days of surgery were 17.20 (sd 7.07) and 18.71 (sd 5.35) respectively. The scores were normally distributed for both those discharged within five days (K-S Z = 0.428, p = 0.993), and those discharged after five days (K-S Z = 0.678, p = 0.747).

There was no significant difference in the scores of patients discharged within five days and those who had a longer PLOS (t = 0.994, df = 65; p = 0.324), equal variances assumed (F = 3.24; p = 0.077).

6.4.4 MULTIDIMENSIONAL HEALTH LOCUS OF CONTROL – POWERFUL OTHERS

The powerful others items of MHLC were scored for 67 patients (13.3%), a response rate of 29.3% of eligible patients. The scores ranged from 11-36 (mean 24.99, sd 5.61) and were normally distributed (K-S Z = 0.601, p =

0.862).

Hypothesis 1

There was no significant association between PSS score and PLOS (r_s = 0.13; n = 67; p = 0.303).

Hypothesis 2

The mean scores of patients discharged within and after five days of surgery were 23.51 (sd 5.66) and 26.11 (sd 5.38) respectively. The scores were normally distributed for those discharged within five days (K-S Z = 0.470, p = 0.980), and those discharged after five days (K-S Z = 0.699, p = 0.712).

There was no significant difference in the scores of patients discharged within five days and those who had a longer PLOS (t = 1.917, df = 65; p = 0.060), equal variances assumed (F = 1.30; p = 0.719).

6.4.5 SUMMARY OF THE UNIVARIATE TESTS FOR PYSCHOLOGICAL VARIABLES

Table 6.4.5.1 summarises the results of the univariate tests for psychological variables and shows that perceived stress and health locus of control scores were not associated with PLOS or discharge within five days of CABG.

TABLE 6.4.5.1:
SUMMARY OF THE RESULTS OF THE UNIVARIATE TESTS FOR PSYCHOLOGICAL VARIABLES

Variable	N	% of sample	Response rate	Association with PLOS	Association with PLOS ≤ 5 days
Perceived Stress Scale	67	13.3	29.3	r_s = 0.08; n = 67; p = 0.499	t = 0.023, df = 64.99; p = 0.982
MHLC - Internal items score	68	13.5	29.7	r_s = 0.11; n = 68; p = 0.376	t = 0.165, df = 66; p = 0.248
MHLC - Chance items score	67	13.3	29.3	r_s = 0.14; n = 67; p = 0.256	t = 0.994, df = 65; p = 0.324
MHLC - Powerful others score	67	13.3	29.3	r_s = 0.13; n = 67; p = 0.303	t = 1.917, df = 65; p = 0.060

Table 6.4.5.2 illustrates the associations between perceived stress score and the scores on the MHLC items. The table shows that none of the scores on the MHLC items were significantly associated with perceived stress scores.

TABLE 6.4.5.2:
ASSOCIATIONS BETWEEN PERCEIVED STRESS AND THE MULTIDIMENSIONAL HEALTH LOCUS OF CONTROL ITEMS

		MHLC - Internal items score	MHLC - Chance items score	MHLC - Powerful others score
Perceived Stress Scale score	r_s	$r_s =$ .026	.214	.174
	p	.835	.084	.162
	N	67	66	66
MHLOC - Internal items score	r_s		.275	.220
	P		.025	.074
	N		67	67
MHLOC - Chance items score	r_s			.463
	p			.000
	N			67

The characteristics of patients who completed the psychological questionnaires compared to those who did not

The PLOS for patients who completed the questionnaires in Phase II ranged from three to 33 days. The mean, median and modal PLOS were 6.90 days (s.d. 4.00 days), six days (IQR 5-8 days), and five days respectively. A total of 30 patients (44.1%) were discharged within five days of surgery compared to 38 patients (55.9%) who were discharged after five days.

The summary PLOS statistics for patients who did not complete the questionnaires and were therefore not included in the analysis of the psychological variables were similar. PLOS ranged from four to 105 days while the mean, median and modal PLOS were 8.42 days (s.d. 8.08 days), six days (IQR 5-8 days), and five days respectively. A total of 171 patients

(39.3%) were discharged within five days of surgery compared to 264 patients (60.7%) who were discharged after five days.

However, a comparison of the characteristics of the sample of patients who completed the questionnaires with those that did not showed that the sampling method used had resulted in a selection bias in favour of younger, lower risk, elective patients with fewer co-morbid conditions. They were also less likely to be widowed, living alone and more likely to be male and working. This has implications for the interpretation of the results which are discussed in the following chapter.

Tables 6.4.5.3 and 6.4.5.4 show the characteristics of patients who were included in the analysis of the psychological variables and those patients who did not complete the psychological questionnaires.

TABLE 6.4.5.3:
CHARACTERISTICS OF THE PATIENTS WHO COMPLETED THE PSYCHOLOGICAL QUESTIONNAIRES AND THOSE WHO DID NOT (CONTINUOUS VARIABLES).

Variable	Patients who completed psychological questionnaires Mean (s.d.)	Patients who did not complete psychological questionnaires Mean (s.d.)	Total Phase II Sample Mean (s.d.)
Age	64.40 (10.93)	65.3 (10.44)	65.2 (10.5)
BSA	1.93 (0.24)	1.89 (0.27)	1.90 (0.26)
BMI	28.71 (5.80)	27.5 (4.38)	27.70 (4.60)
No. Vessels Bypassed	2.85 (0.85)	3.10 (0.88)	3.07 (0.88)
Parsonnet Score	8.77 (6.82)	9.34 (6.95)	9.27 (6.93)
EuroSCORE	2.70 (2.49)	3.96 (6.94)	3.79 (3.03)
IMD 2004	19.16 (12.45)	25.61 (14.73)	24.73 (14.60)

TABLE 6.4.5.4:
CHARACTERISTICS OF THE PATIENTS WHO COMPLETED THE PSYCHOLOGICAL QUESTIONNAIRES AND THOSE WHO DID NOT (CATEGORICAL VARIABLES).

Variable	Categories	Patients who completed psychological questionnaires		Patients who did not complete psychological questionnaires		Total Phase II Sample	
		N	%	N	%	N	%
Sample		68	13.5	435	86.5	503	100
Age Category	< 51	8	11.8	44	10.1	52	10.3
	51-60	17	25	88	20.2	105	20.9
	61-70	22	32.4	142	32.6	164	32.6
	>70	21	30.9	161	37.0	182	36.2
Gender	Male	59	86.8	349	80.2	408	81.1
	Female	9	13.2	86	19.8	95	18.9
Diabetes	Not diabetic	45	66.2	270	62.1	315	62.6
	Diabetic	16	23.5	150	34.5	166	33.0
	Diet-controlled Oral therapy	10	14.7	92	21.1	102	20.3
	Insulin therapy	6	8.8	58	13.3	64	12.7
	Missing	7	10.3	15	3.4	22	4.4
Hypertension	No	12	17.6	77	17.1	89	17.7
	Yes	49	72.0	343	78.9	392	77.9
	Missing	7	10.3	15	3.4	22	4.4
Renal Disease	No	57	83.8	403	92.6	460	91.5
	Yes	5	7.4	16	3.7	21	4.2
	Missing	6	8.8	16	3.7	22	4.4
Ejection Fraction	Poor	2	2.9	27	6.2	29	5.8
	Fair	16	23.5	128	29.4	144	28.6
	Good	43	63.2	264	60.7	307	61.0
	Missing	7	10.3	16	3.7	23	4.6
No. Previous MIs	None	42	61.8	217	49.9	259	51.5
	One or more	19	27.9	195	44.8	214	42.5
	Missing	7	10.3	23	5.3	30	6.0
Dyspnoea Classification	NYHA 1	27	39.7	110	25.3	137	27.2
	NYHA 2	25	36.8	207	47.6	232	46.1
	NYHA 3 & 4	9	13.2	98	22.5	107	21.3
	Missing	7	10.3	20	4.6	27	5.4
Angina Classification	CCS 0 & 1	12	17.6	54	12.4	66	13.1
	CCS 2	33	48.5	173	39.8	206	41.0
	CCS 3 & 4	16	23.5	188	43.2	204	40.6
	Missing	7	10.3	20	4.6	27	5.4
Left Main Stem Disease	No	48	70.6	276	63.4	324	64.4
	Yes	13	19.1	138	31.7	151	30.0
	Missing	7	10.3	21	4.8	28	5.6
Peripheral Vascular Disease	No	58	85.3	358	82.3	416	82.7
	Yes	3	4.41	62	14.3	65	12.9
	Missing	7	10.3	15	3.4	22	4.4
Pulmonary Disease	None	55	80.9	350	80.5	405	80.5
	Yes	6	8.8	70	16.1	76	15.1
	Missing	7	10.3	15	3.4	22	4.4
Smoking History	Never smoked	23	33.8	104	23.9	127	25.2
	Ex-smoker	32	47.1	262	60.2	294	58.4
	Current smoker	6	8.8	49	11.3	55	10.9
	Missing	7	10.3	20	4.6	27	5.4

Variable	Categories	Patients who completed psychological questionnaires		Patients who did not complete psychological questionnaires		Total Phase II Sample	
		N	%	N	%	N	%
CPB	No	12	17.6	42	9.7	54	10.7
	Yes	49	72.1	372	85.5	421	83.7
	Missing	7	10.3	21	4.8	28	5.6
Urgency of Surgery	Elective	68	100	251	57.7	319	63.4
	Non Elective	0	0	183	42.1	183	36.4
	Missing	0	0	1	0.2	1	0.2
Time on the Waiting List (months)	0-3	68	100	256	58.9	324	64.4
	>3	0	0	3	0.7	3	0.6
	Not on list	0	0	176	40.5	176	35.0
Preoperative Length of Stay	0-1 days	59	86.8	297	68.3	356	70.8
	2-7 days	7	10.3	88	20.2	95	18.9
	> 1 week	2	2.9	50	11.5	52	10.3
Hospital	1	17	25.0	266	61.1	283	56.3
	2	51	75.0	169	38.9	220	43.7
Day of the week on which the 5th postoperative day occurred.	Sunday	20	29.4	89	20.5	109	21.7
	Monday	5	7.4	101	23.2	106	21.1
	Tuesday	14	20.6	90	20.7	104	20.7
	Wednesday	15	22.1	84	19.3	99	19.7
	Thurs & Fri	0	0	2	0.5	2	0.4
	Saturday	14	20.6	69	15.9	83	16.5
Marital Status	Married/Cohab	56	82.4	308	70.8	364	72.4
	Sep/Divorce	4	5.9	17	3.9	21	4.2
	Single	5	7.4	32	7.4	37	7.4
	Widowed	2	2.9	49	11.3	51	10.1
	Missing	1	1.5	29	6.7	30	6.0
Living Alone	No	60	88.2	349	80.2	409	81.3
	Yes	7	10.3	50	11.5	57	11.3
	Missing	1	1.5	36	8.3	37	7.4
Employment	Retired/unemp.	25	36.8	177	40.7	202	40.2
	Emp./self-emp.	16	23.5	79	18.2	95	18.9
	Missing	27	39.7	179	41.1	206	41.0

CHAPTER 7

DISCUSSION

PURPOSE

This study shows that the ability to predict PLOS in the preoperative period is important to maximise the time available for discharge planning in order to improve the patient experience and increase efficiency. The purpose of the study was to develop models that can be used in clinical practice to predict PLOS and to identify those patients likely to be discharged within five days of CABG.

PREVIOUS WORK

Earlier research focused extensively upon routinely collected demographic and clinical variables and found that PLOS is poorly predicted by these variables. However, the failure to investigate the potential influence of psychosocial variables such as marital status, and socioeconomic circumstances had resulted in a gap in the understanding of predicting PLOS. Previous work is also not underpinned by theory which is important for building knowledge (Polit and Beck, 2004).

THIS STUDY

This study has attempted to address these gaps in knowledge by applying the theory of “stress, appraisal and coping” (Lazarus and Folkman, 1984) and investigating psychosocial as well as demographic and clinical predicators of PLOS and discharge within five days of CABG. The application of the theoretical framework has also generated a new area of research into the investigation of perceived stress, health locus of control and their influence on PLOS.

METHODOLOGY

The research question and the aims of the study were addressed using a quantitative observational approach. Statistical models were developed from a retrospective secondary analysis of audit data and routinely collected patient information for a cross-section of patients (Phase I). These were prospectively validated on another cohort of patients (Phase II).

FINDINGS

The models identified psychosocial as well as clinical variables as important predictors of PLOS and discharge within five days but the psychosocial variables included in this study did not improve the predictive ability of earlier models. The selection and measurement of psychosocial variables is problematic but expanding the investigation to include other psychosocial variables is identified as important to the development of these models and central to the direction of future research in this area.

The logistic regression models were much better at predicting which patients would be discharged after five days. Identifying patients who are unlikely to be discharged within five days may improve care and reduce PLOS for this group of patients, as well as increasing the number of patients who are discharged within five days.

The results of this study provide a contemporary analysis of the variables that are associated with PLOS, including previously neglected psychosocial variables, and general trends in the local CABG population. These findings also have high external validity due to the characteristics of the research sample, the setting of the study and the use of observational methods that preserve the context of the research setting.

The discussion of the study is organised into six sections. The findings and the methods used in the study are discussed in section 7.1 and 7.2 respectively. The internal and external validity of the findings are examined in section 7.3 and 7.4 respectively. The application of the findings is explored in section 7.5, and recommendations for further study are made in section 7.6.

7.1 FINDINGS

7.1.1 SHORTER POSTOPERATIVE LENGTH OF STAY

The results reflected the general trend to discharge patients earlier in their recovery after CABG. The results showed a shorter mean (8.2 days) and median (6 days) PLOS when compared to studies conducted in previous decades such as Weintraub et al (1989) (9.1 days and 7.0 days) and Rosen et al (1999) (11.1days and 8.0 days).

7.1.1.1 Case mix and advances in care

This observed reduction in PLOS has occurred despite a worsening case mix of CABG patients. The proportions of demographic and preoperative variables such as age and morbidity are known to vary over time as reported in successive NACS database reports (Keogh and Kinsman, 2002; 2004). Not only have the characteristics of the CABG population changed in line with the demographics of the population but more referrals are now for older and high risk patients (Keogh and Kinsman, 2004).

The impact of this worsening case mix on PLOS has been countered by advances in care. Concurrent developments in surgical, anaesthetic and pharmacological practice together with the implementation of rapid recovery programs and integrated care pathways have enabled patients to recover quicker than in the past.

7.1.1.2 Cost

The increased demand for CABG from a worsening case mix of patients has also lead to financial pressures which have undoubtedly influenced practice towards shorter PLOS. However, the relationship between early discharge, patient outcomes and true cost savings is a highly complex one. The literature demonstrates that cost savings may be made by the hospital of surgery by decreasing PLOS, but it is not clear if total costs are reduced because the cost may simply have been re-directed to the referring hospital or into the community (Sanchez et al, 1994; Birdi et al, 1995; Lazar et al, 2001).

7.1.1.3 Patient outcomes

Previous studies have suggested that reductions in PLOS over time can be achieved without an increase in morbidity, mortality or readmission rates and may actually have improved these clinical outcomes (Krohn et al, 1990; Nikas et al, 1996; Velaso et al, 1996; Cohn et al, 1997; Cowper et al, 1997; Weintraub et al, 1998; Bohmer et al, 2002; Booth et al, 2004). However, mortality, morbidity and readmission rates are simplistic measures of patient outcomes with readmission rates in particular lacking completeness because they are rarely tracked beyond the hospital of surgery.

Patient-reported outcome measures regarding their experience have often been neglected which means that our understanding of the impact of shorter PLOS has been over-simplistic. As the collection of patient-reported measures become a requirement for healthcare providers it is likely that more information about these outcomes will be made available in the future (Care Quality Commission, 2010).

Although the impact on cost and patient outcomes is not clear, the shorter PLOS currently observed after CABG does increase the importance of early discharge planning, either preadmission or on actual admission; as the time available to plan and provide discharge care has been reduced.

7.1.2 PROLONGED POSTOPERATIVE LENGTH OF STAY

Similar to the previous studies, the findings of the current study showed a long statistical tail of a few patients with prolonged PLOS that positively skewed the mean of the population (Weintraub et al, 1989; Rosen et al, 1999; Peterson et al, 2002; Contrada et al, 2004, Oxlad et al, 2006). These outliers may exert undue influence on statistical tests based on population means and assuming normal distributions. Consequently this relatively complex distribution of PLOS must be taken into account when analysing, interpreting and comparing research findings since decisions regarding the handling of such data have implications for the findings of these analyses.

7.1.2.1 Analysing non normal distributions

The frequent practice of measuring the mean PLOS and using parametric techniques for analysing what is often not normally distributed but skewed data, may not be the most suitable guide of PLOS in this population since they are sensitive to outlying and extreme values. Previous multivariate analyses have transformed their data to obtain distributions more suitable for multiple regression (Weintraub et al, 1989; Rosen et al, 1999; Peterson et al, 2002; Contrada et al, 2004, Oxlad et al, 2006). However, in the current study, the non-normal distribution of PLOS remained even when a log transformation was attempted, and the influence of outlying values was taken into account. Non parametric tests were therefore utilised due to serious violations in the distribution of PLOS to meet the assumptions underlying the use of the parametric tests. Population means were reported for comparative purposes only.

Outliers with a PLOS of more than 12 days were excluded from the multivariate analysis of PLOS since this improved the symmetry of the data, consistent with the assumptions for the use of the multivariate ANOVA statistic. This resulted in a more accurate account of 90% of the sample by removing the undue influence of patients with excessively long PLOS. Previous analyses that do not indicate if they have removed extreme and outlying values from their analysis may have provided less accurate accounts of their samples (Weintraub et al, 1989; Rosen et al, 1999; Peterson et al, 2002; Contrada et al, 2004, Oxlad et al, 2006).

7.1.3 FIVE-DAY DISCHARGE

The five-day cut-off point for discharge was selected to reflect the current aims of discharge practice at the study centre. A modal value of discharge on postoperative day five for both Phases I and II indicated that this was the day on which most discharges occurred in the local population and therefore confirmed this as being locally the most clinically relevant and useful when planning services.

The results also reflected the general increase in the proportion of patients discharged within five days of their operation that has been reported nationally (Keogh and Kinsman, 2001). Nearly 40% of patients in the current study were discharged within five days compared to approximately 20% of the wider population during 1999-2000 (Keogh and Kinsman, 2001).

Whilst this study confirms that more patients are being discharged within five days of CABG, a greater proportion of patients are discharged after this day. There was clear evidence that 60% of patients who underwent first time isolated CABG at the study centre failed to achieve the five-day discharge to which all patients were routinely assigned. These results suggest that this universal five-day discharge plan was either not appropriate to these patients' circumstances or not achieved due to avoidable (clinical, practical or social) reasons or non-avoidable (clinical) reasons.

This finding confirms the importance of preoperatively identifying which patients are likely to meet the five-day target in order to ensure that they are assigned to an appropriate discharge plan. This will ensure that patients who are not likely to achieve discharge within five days are not assigned to discharge plans that do not reflect their individual circumstances. This will also minimise the stress that may be caused by not achieving the five-day target for patients in this group.

Whilst practising at one of the study hospitals, the author perceived that more patients might have been discharged by postoperative day five if there had been greater consensus and consistency in aiming for this target by the multidisciplinary team for identified patients. The implementation of models to predict discharge within five days may therefore increase the number of patients achieving this target by facilitating greater consensus and consistency among the multidisciplinary team and reducing unnecessary delays in the decision to discharge a patient when they are fit for discharge.

7.1.4 PHASE I: THE IDENTIFICATION OF POTENTIAL PREDICTORS

Phase I of the study consisted of a univariate analysis of each variable to test hypotheses 1 and 2, and identify potential predictors of PLOS and discharge within five days of CABG respectively.

The results of the univariate analysis identified 19 potential predictors for both PLOS and discharge within five days; age, gender, body surface area (BSA), body mass index (BMI) category (hypothesis 1 only), marital status, living alone, employment status, deprivation index, diabetes, renal disease, ejection fraction, dyspnoea, angina, peripheral vascular disease (PVD), pulmonary disease, Parsonnet score, EuroSCORE, urgency of surgery, time on the waiting list, preoperative length of stay, and day on which the fifth postoperative day occurred (hypothesis 2 only).

All the variables included in Phase I were selected based on previous empirical support of at least a univariate association with PLOS. The identification of these variables therefore supports the findings of previous studies that have also reported univariate associations of these variables with PLOS after cardiac surgery (Weintraub et al, 1989; Lahey et al, 1992; Lazer et al, 1995; Tu et al, 1995; Miller et al, 1998; Rosen et al, 1999; Peterson et al, 2002; Taylor, 2003; Johnson, 2004; Toumpoulis et al, 2005; Anderson et al, 2006.

Potential predictors were identified from each of the variable groups studied; demographic, co-morbidity; severity of illness and operative/organisational variables.

7.1.4.1 Demographic variables

This study identified potential predictors from a much broader group of demographic variables than any previous multivariate analysis. This demographic group of variables included several psychosocial variables; age, gender, body size (BSA and BMI), marital status, living alone, employment status, socioeconomic deprivation and ethnic group. The results showed that this group of variables had an important influence on PLOS and discharge within five days.

Age, gender, body size (BSA and BMI), marital status, living alone employment status, and socioeconomic deprivation were all identified as potential predictors. Older patients, being female, smaller body size, being widowed, living alone, not working, and living in an area of higher socioeconomic deprivation were all associated with longer PLOS and discharge after five days of surgery.

The association of these variables with PLOS is largely consistent with the results of previous analyses (Weintraub et al, 1989; Mounsey et al, 1995; Paone et al, 1998; Aldea et al, 1999; Rosen et al, 1999; Curtis et al, 2002; Peterson et al, 2002; Taylor et al, 2003; Johnson et al, 2004). Age, gender and body size have been extensively studied and the findings of this study therefore confirm that these variables remain associated with PLOS in the contemporary local population studied. However, the analysis of living alone, employment status and index of deprivation shows that this group of variables, seldom investigated in the prediction of PLOS, are also independently associated with PLOS and confound the influence of the variables that have been traditionally studied.

There were some differences with the findings of previous studies although these may reflect key differences in the methods used. For example, Curtis et al (2002) did not find any association of BSA with prolonged PLOS of more than 14 days but this finding is specific to this definition of prolonged PLOS and suggests that whilst BSA is associated with shorter PLOS it may not be associated with very long definitions of prolonged PLOS. Similarly, the findings that living alone was associated with longer PLOS and discharge after five days are in contrast to those reported by Anderson et al (2006) but these may reflect differences between this study sample and the all male, elderly white sample investigated in the their study.

Mechanisms of influence

There are several explanations for why the demographic variables identified as potential predictors may influence PLOS. Exploring these possible explanations can inform future analyses by identifying confounding variables for further investigation.

Physiological differences

There are many age-related differences in physiological recovery that mean older people generally tolerate surgery less well than younger people, which may result in a slower postoperative recovery. These include changes to the myocardium, increased stiffness of the great arteries resulting in increased afterload, changes in excitation-contraction coupling leading to prolonged contraction and myocardial stiffness, and also the development of collagenous tissue over the conduction pathways (Margereson and Riley, 2003). The myocardium becomes more sensitive with age to ischemia, whilst arrhythmias and hypertension are also more common with advancing age (Margereson and Riley, 2003).

Age-related changes occurring in other major body systems that may impact on recovery include, decreased respiratory muscle strength, less compliant lungs, decreased glomerular filtration rate, decreased renal tubular function, and also reduced hepatic function (Margereson and Riley, 2003).

Men tend to develop coronary artery disease at younger ages with the onset of the disease in women beginning with the onset of the menopause (American Heart Association, 1998). Meanwhile, the smaller body size and smaller coronary arteries of women and the relatively greater effect of cardiopulmonary bypass on body physiology of smaller people may explain their longer PLOS (Shiefer et al, 2000; Kim et al, 2004; Keogh and Kinsman, 2004).

The results showed that BSA was more closely associated with PLOS and discharge within five days than BMI. The closer association of BSA with PLOS and discharge within five days may reflect the fact that BSA is also positively associated with coronary artery luminal diameter (Kim et al, 2004). Smaller coronary artery diameter may be responsible for the increased PLOS observed in smaller people by resulting in a more technically demanding operation (Keogh and Kinsman, 2004).

Psychosocial and cultural differences

The influence of age and gender, may also reflect the importance of less quantifiable variables such as social circumstances that may impact upon recovery and discharge from hospital.

It has been suggested that gender differences in recovery from CABG could result from differences in the ways men and women perceive and respond to coronary artery disease and CABG, to bias on the part of healthcare workers who may respond differently to men and women, and differences in social roles, and expectations, and the psychological profile of men and women undergoing CABG, (Sokol et al, 1987; Rankin, 1990; King et al, 1992a; Hawthorne, 1994; Artinian and Duggan, 1995; Girard, 1995; Czajkoski et al, 1997; King, 1997; Butterworth et al, 2000).

The influence of age and gender may also be explained by socioeconomic factors influencing access to resources to aid recovery. The literature suggests that women are likely to be more economically disadvantaged and socially isolated when they age, with studies consistently reporting that women undergoing CABG are more likely to be widowed, living alone, unemployed, with lower education and lower family incomes than men (Hawthorne, 1994; Artinian and Duggan, 1995; Ayanian et al, 1995; Moore, 1995; King, 2000). King (2000) argued that when followed over the postoperative course and multiple facets of recovery are considered, few gender differences are found and tend to be related to social support and other psychosocial factors that existed preoperatively rather than biophysical differences.

The results of the study suggest that future analyses should categorise age according to whether PLOS is being measured as a continuous or categorical outcome. There were no significant differences between the PLOS of the youngest two groups which suggests that age may be better categorised using two or three levels centred around the older groups; such as a dichotomy of age over or under 70 years old, or three groups consisting of age over 70 years, 61-70 years, and 60 years or under, in future investigations of PLOS. The youngest group was also small in comparison to the other groups (n = 58) and probably reflected a group with more severe disease developing at an early age which resulted in higher, but not significantly so, median PLOS than patients in the next age group.

In contrast, being in the youngest age group was important for the analysis of discharge within five days. The 51-60 years age group was the only group in which more patients were discharged within five days of surgery than after the fifth postoperative day. This may reflect the increased stress associated with developing more severe disease at an early age and the implications for the patient's socioeconomic role in the family. Patients undergoing CABG at an early age may be more likely to have the physical and socioeconomic resources for coping with it than older patients. Such patients may otherwise be physically fit and more likely to have both younger and older dependents that motivate them to return to fitness and paid employment. Future analyses should therefore ensure that this group is maintained in the categorisation of age and discharge within five days.

Living alone can often necessitate the wait for a bed to become available at the patient's local hospital if assistance from other relatives and friends is not available. This factor probably explains much of how this variable can lengthen PLOS but as data on both the destination at discharge and the date the patient was medically fit for discharge was not collected it is not possible to analyse this further in the current study.

The study therefore identifies a new potential variable, namely "destination on discharge", that should be studied further to investigate any association with PLOS and discharge within five days. This study also justifies the collection of data regarding the date a patient was actually medically fit for discharge, in addition to the date of actual discharge, in order to explore the mechanisms by which destination of discharge may exert an influence.

Confounding variables

The apparent relationship between any of the variables and PLOS or discharge within five days may have been spurious due to the influence of confounding variables. Older age for example, is known to be associated with other demographic variables in the study such as female gender, smaller body size, being widowed and living alone which may play an important role in creating the difference observed in PLOS (Aldea et al, 1999; Miller and Grindel, 1999; 2001; Woods et al, 2003; Johnson et al, 2002).

Similarly, it is arguable that elderly patients may experience longer PLOS because they have more preoperative co-morbidity including diabetes and renal dysfunction, that increase the risk of postoperative complications in this group, and are more likely to require emergency surgery (see for example Zaidi et al, 1999; Zacek et al, 2001; Eagle and Guyton et al, 2004).

Consistent with these findings, confounding variables were not equally distributed by age. Patients in the older age groups in the current study were more likely to be female, live alone, widowed, have more co-morbidity and more likely to undergo non-elective surgery. Hence, it is difficult to reach an unequivocal decision about the independent effects of the variables identified as potential predictors of PLOS and discharge within five days when possible confounding variables are also independently associated with these outcomes. The lack of control for confounding variables and the unequal distribution of these variables across the groups, make it difficult to attribute the outcomes observed to the variable studied because alternative explanations cannot be excluded.

These findings highlight the complexity of the interactions between physiological and psychosocial elements of the variables studied, and their influence on PLOS. This, in turn, highlights the importance of including psychosocial variables in the multivariate analysis of PLOS in order to fully investigate the complexity of predicting PLOS and increase the accuracy of prediction models.

Whatever the mechanism is by which these demographic variables influence

PLOS, this study confirms the relative importance of this group of variables. The influence of these variables is also likely to become more pronounced as the population ages and the trend towards operating on increasingly older patients who are more likely to be female, have a smaller body size, be widowed, living alone and not working, continues. The collection of data on psychosocial variables for the investigation of the multivariate prediction of PLOS is therefore justified as a result of this study.

Ethnic Group

Ethnic group was the only demographic variable not identified as a potential predictor of PLOS or discharge within five days in the current study. The non-white ethnic groups accounted for less than 20% of the sample and were subsequently combined for the analysis due to the small group sizes within the non-white ethnic groups. The non significant finding may therefore be due to the reclassification of all non-white ethnic groups.

The closer inspection of the ethnic group data showed variation in the patient profile between the non-white ethnic groups. For example, Chinese patients were the oldest and highest risk group, while black or black British patients had the highest deprivation scores. This heterogeneity within the non-white group, and the loss of detail resulting from the reclassification, may have masked a possible effect of belonging to the original non-white ethnic groups. Similar to the other variables in the study, the comparisons of the original ethnic groups also demonstrate that any influence due to ethnic group is potentially confounded by many other variables. Future analyses, using larger samples, should therefore adjust for both the sample size of the non-white groups and confounding variables.

7.1.4.2 Co-morbidity variables

The co-morbidity variables included in the study had been extensively studied previously and the importance of their influence on PLOS established. The findings showed that this group of variables remained important determinants of PLOS and discharge within five days in the contemporary local population. However, the relative importance of the individual co-morbidity variables may be changing in line with the characteristics of patients presenting for CABG and the demographics of the general population.

Similar to the findings of previous studies, the presence of diabetes, renal failure, poor ejection fraction, dyspnoea, angina and peripheral vascular disease were all observed to significantly increase PLOS and decrease the likelihood of discharge within five days (Weintraub et al, 1989; Lazar et al, 1995; Mounsey et al, 1995; Paone et al, 1998; Rosen, 1999; Curtis et al, 2002; Peterson et al, 2002; Johnson et al, 2004; Keogh and Kinsman, 2004; Anderson et al, 2006).

The magnitude of the effect on PLOS by diabetes, renal disease and peripheral vascular disease was consistent with national trends, prolonging PLOS by an average of 1.5 days, 5.0 days, and 2.7 days respectively (Keogh and Kinsman, 2004). Similarly, the prevalence of these variables was higher in the study population reflecting the increase in the proportion of patients presenting for CABG surgery with diabetes and renal disease in line with the demographics of the population (Keogh and Kinsman, 2004). The influence of these variables on PLOS is therefore likely to become more pronounced.

In contrast, the prevalence of severe dyspnoea was less in the study sample than the wider population but the magnitude of the effect on PLOS was higher. Patients with the most severe dyspnoea spent an average of 2.9 days longer in hospital than patients with the least severe which is more than the two days reported by Keogh and Kinsman (2004). These findings suggest that not only is the prevalence of dyspnoea increasing in the wider CABG population but that the magnitude and relative influence of dyspnoea on PLOS could also be increasing.

The prevalence of poor ejection fraction in the study sample was comparable to the wider population but the influence of this variable on PLOS was less. Patients with a good ejection fraction spent on average one day less in hospital than those with a poor ejection fraction compared to the three days reported previously (Keogh and Kinsman, 2004), an influence that was reported to be stable at the time.

Mechanisms of influence

The mechanisms by which these co-morbidity variables exert a physiological influence PLOS is fairly well established. However, their effect is generally confounded by age, gender and other co-morbidity variables.

For example, the adverse effects from hyperglycaemia in diabetic patients have been shown to influence their clinical course after CABG via several mechanisms including dehydration, electrolyte disorders, and delayed wound healing (Davi et al, 1990; Vague et al, 1992; McMohan et al, 1995; Herlitz et al, 1996; Williams et al, 1998; Thourani et al, 1999; Carlson et al, 2002). Similarly, there are a number of physiological mechanisms by which renal impairment can complicate recovery from CABG surgery including; decreased drug elimination, hypervolaemia, hyperkalaemia, bleeding due to platelet dysfunction, anaemia and encephalopathy (Bakris et al, 2006; Cooper et al, 2006, Hillis et al, 2006).

At the same time, evidence suggests that diabetic CABG patients are more likely to be women, and present with more diffuse coronary artery disease and more co-morbidities such as left ventricular hypertrophy, a history of cerebrovascular disease, hypertension, chronic obstructive pulmonary disease, and higher creatinine levels than non-diabetic patients that may also influence their PLOS (Thourani et al, 1999; Carson et al, 2003; Szabo et al, 2002; Herlitz et al, 2000; Keogh and Kinsman, 2004; Woods et al, 2004).

Meanwhile, CABG patients with renal dysfunction are also more likely to be older, diabetic, hypertensive, and suffer from peripheral vascular disease and left ventricular dysfunction which are themselves associated with longer PLOS (Keogh and Kinsman, 2004). Patient with renal disease are also more likely to have higher levels of social deprivation and also be of Afro-Caribbean and South Asian origin which may also influence PLOS

(Department of Health Renal Team, 2004, The Renal Association, 2005).

In the study sample, there was no difference in the distribution of diabetes between male and female patients in the sample thus suggesting that gender was unlikely to have confounded the influence of diabetes on PLOS. However, other variables, such as urgency of surgery and renal disease were not equally distributed between the diabetic groups. Similarly, there was also no difference in the mean age of patients with and without renal disease but peripheral vascular disease, poor ejection fraction and deprivation index scores were not evenly distributed between the renal groups.

The unequal distribution of co-morbidity between the groups was similar for the other co-morbidity variables that were identified as potential predictors of PLOS and discharge within five days. Again, the failure to achieve equal variances between the groups means that those variables not equally distributed may confound the influence on PLOS.

Co-morbidity variables not identified as potential predictors

Hypertension, previous myocardial infarction and smoking history were not identified as potential predictors. These findings were in contrast to previous findings.

The non-significant findings for hypertension and previous myocardial infarction are in contrast to the results of previous univariate analyses (Weintraub et al, 1989; Paone et al, 1998; Curtis et al, 2002). It is also in contrast to the trends reported by Keogh and Kinsman (2004) who found that the influence of hypertension on PLOS had increased from 0.4 days to one day between 1999 and 2003, whilst patients who experienced a previous myocardial infarction spent an average of 0.5 days longer in hospital, an influence that had remained a stable since the late 1990's.

A possible explanation for this inconsistency is that the influence of hypertension and angina on PLOS is now decreasing due to improved management of these conditions and changes to operative and postoperative management. Alternatively, a deviant sample may have been selected and further study is therefore required to validate the findings in another cross-section or cohort of patients before a definitive conclusion of the influence of a previous myocardial infarction on PLOS can be reached.

The non significant finding for smoking history is in contrast to the findings of Oxlad et al (2006). This may be reflective of differences in the populations studied. Alternatively, this may be the result of analysing incomplete audit data that excluded proportionally more patients with pulmonary disease who may have been more likely to be current or ex- smokers.

7.1.4.3 Severity of illness variables

The following variables reflecting the severity of the patient's illness were identified as potential predictors of PLOS: mortality risk (Parsonnet score and EuroSCORE), urgency of surgery, time on the waiting list and preoperative length of stay. These variables are however, very much interrelated and also dependent on co-morbidity variables.

Mortality risk

The finding that predicted mortality risks, similar to the variables used to calculate them, were positively associated with PLOS is consistent with earlier work (Miller et al, 1998; Keogh and Kinsman, 1999; Ott et al, 2000; Riordan et al, 2000; Kurki et al, 2001; Peterson et al, 2002; Toumpoulis et al, 2005). As patients undergoing CABG are increasingly higher risk (Keogh and Kinsman, 2004), the influence of mortality risk on PLOS is likely to have an increasing impact.

However, there was little difference in the results of the Parsonnet score from hard data and the more subjective Parsonnet score with catastrophic states and rare conditions included. This was not expected since the subjective weight decided by the surgeon for catastrophic states and rare conditions (10-50) can have a major effect on the calculation of the score and result in wide fluctuations.

Urgency of surgery

Non-elective surgery has previously been associated with longer PLOS (Weintraub et al, 1989; Paone et al, 1998; Aldea et al, 1999; Curtis et al, 2002; Peterson et al, 2002). This consensus over time and between studies suggests that the urgency of surgery has a stable and enduring influence on PLOS despite advances in care.

Mechanisms of influence and confounding variables

The urgency of surgery is an established risk factor for poorer outcomes after CABG which may physiologically explain the longer PLOS associated with non-elective surgery (Kurki et al, 2003; Keogh and Kinsman, 2004). However, for patients undergoing non-elective CABG, the threat to their well-being is imminent which, in accordance with the theoretical framework of the study, may influence their appraisal of the event and their subsequent selection of coping strategies (Lazarus and Folkman, 1984).

The opportunity for psychological preparation in the form of preoperative information which can then be used in the secondary appraisal of impending CABG is vastly reduced for patients undergoing non-elective CABG. Theoretically, this may lead to the selection of less effective emotion-based coping strategies which may also contribute to the longer PLOS observed in this group of patients. However, the urgency of surgery was not associated with stress appraisals, and stress appraisals were not associated with PLOS in this study.

The urgency of surgery may also be confounded by other variables such as increasing age and gender as non-elective CABG surgery is more common in women and older patients (Hannan et al, 1992; Weintraub et al, 1993; Keogh and Kinsman, 2002). The urgency of surgery was evenly distributed by gender in the current study but not by age.

The urgency of surgery is also directly linked to the time a patient waits for CABG. Patients who did not wait on the waiting list were more likely to have undergone non-elective surgery (76.1%, n = 232 vs. 14.4%, n = 52).

Patients who were on the waiting list were also a lower risk group (mean Parsonnet score 8.8 sd 6.2 vs. 10.4 sd 7.1).

Vast improvements in waiting times are likely to have reduced the impact of this variable as, officially, no patients wait more than three months for CABG in the UK and waiting times recorded in this way are expected to decrease further (Department of Health Coronary Heart Disease Policy Team, 2007). This reduction in waiting time is likely to have removed some of the anxiety that has been associated with the uncertainty of waiting for CABG as patients now know that they can expect to be treated within three months (Fitzsimons et al, 2000; 2003). The adverse effects on the physical and emotional well-being of patients that have been associated with long waits have also been eliminated (Underwood et al, 1993; Bengston et al, 1994; Sampalis et al, 2001).

Time spent on the waiting list may be influenced by many factors. It is necessarily confounded by the severity of the patient's condition and the urgency of their surgery. It may also reflect patient choice as some patients may prefer to wait in order to be operated on by a specific surgeon. Organisational issues may also play a role such as the availability of intensive care beds that mean some patients may have their operation cancelled at short notice and rescheduled for a later date. These latter possibilities were not investigated in the current study, due to difficulties in obtaining this information and so the extent to which these may have confounded the results is not known.

The identification of preoperative length of stay as a potential predictor is consistent with previous univariate analyses that have associated preoperative stays greater than two and eight days with increased PLOS (Lazar et al, 1995; Johnson et al, 2004). However, the patient's preoperative length of stay is influenced by the patient's operative risk and the urgency of their surgery. Patients in the study who were admitted more than one week before surgery were a higher risk group than patients admitted less than one week before surgery and were more likely to have undergone non-elective surgery.

These variables therefore confound the influence of preoperative length of stay and are probably more accurate measures of the patient's preoperative condition than the time they spend at the hospital of surgery waiting for CABG. This is due to the lack of data regarding patients who waited for their surgery at their referring hospital, and the failure therefore to include this waiting time in the analysis. Where this occurred, the date of admission to the hospital of surgery was used to calculate preoperative length of stay rather than the initial date of hospitalisation at another hospital outside of the Trust which contaminates the data. The date the referral was accepted may have more accurately reflected the overall preoperative length of stay in these circumstances.

Severity of illness variables not identified as potential predictors

The presence of left main stem disease and the number of vessels bypassed were not associated with either PLOS or discharge within five days of surgery.

This non-significant finding for left main stem disease is consistent with the findings reported by Paone et al (1998) but it is in contrast to the findings of Weintraub et al (1989), Peterson et al (2002), and the small but increasing difference in PLOS between patients with and without left main stem disease observed in the NACS database (Keogh and Kinsman, 2004). It is possible that this inconsistency may be due temporal changes in postoperative management since the earlier studies or as the result of analysing incomplete data from both the NACS database and the current study.

Similarly, the non-significant finding for the number of vessels bypassed is in contrast to previous work (Weintraub et al, 1989; Mounsey et al, 1995; Anderson et al, 2006). This may reflect differences in the characteristics of the samples and populations studied or temporal changes to care since the earlier studies. Since the second half of the 1990's there has been a steady reduction in the proportion of patients receiving four bypass grafts, with a concomitant increase in the proportion receiving two or three grafts. This may reflect the worsening pattern of coronary artery disease in patients being considered for surgery, with fewer arteries being suitable for grafting or differences in surgical philosophy (Keogh and Kinsman, 2004).

7.1.4.4 Operative and organizational variables

None of the operative/organisational variables studied were identified as potential predictors of PLOS. The day on which the fifth postoperative day occurred was the only operative/organisational variable observed to have an effect on discharge within five days.

Where the fifth postoperative day occurred on a Tuesday, this was associated with the lowest chance of discharge within five days, followed by a Monday, then Wednesday. The greatest chance of being discharged within five days occurred when the fifth postoperative day was a Saturday or Sunday.

These findings may reflect the practicalities of planning for discharge on different days of the week and the routine pressures on time and beds particular to that day of the week. Greater planning and preparation is required by hospital staff discharging patients at the weekend when both hospital and community services are reduced and less accessible. There is also a greater pressure on ward beds at the weekend as none are vacated by patients going to theatre. The findings may also reflect the practicalities of relatives being more available to collect and care for their family member at the weekend and the ease and reduced cost of most forms transport to the Capital at the weekend.

Whilst being highly influenced by the organisational influences mentioned, this variable is also confounded by consultant surgeons who operate on certain days of the week and may accept differing risk profiles of patients according to their level of experience. However, there was no association between consultant surgeon and discharge within five days of surgery and none of the differences in PLOS between the consultant surgeons were significant when adjustment was made for multiple comparisons. This may have been because the Bonferroni adjustment method used is considered to be too conservative a test if the number of pair-wise comparisons is greater than five (Perneger, 1998). Thus while robust and unlikely to produce a Type I error, it is not very powerful and is quite likely to give a type II error as the number of pair-wise comparisons increase. However, the turnover of consultant staff during the study period added further justification for not including this variable in the multivariate analysis.

These non-significant findings may also reflect that, whilst individual consultant surgeons take principal responsibility for the clinical outcomes of their patients, many variables impact upon the decision to discharge a patient which is frequently made by more junior medical staff. The characteristics of patients treated by each surgeon may also differ and confound the influence of this variable although the mean mortality risk scores for patients under the care of each consultant in this study were similar.

The hospital site may not have influenced PLOS and discharge within five days because some surgeons and other key staff worked across both sites and the hospitals were part of the same directorate with shared policies and protocols. As a result, there was probably little organisational difference between the two hospitals studied. There was also little difference in the characteristics of patients treated at either hospital in terms of age, gender, mortality risk score and urgency of surgery.

The finding that the use of cardiopulmonary bypass was not associated with either PLOS or discharge within five days of surgery is consistent with some previous case-matched studies and randomised controlled trials which have been unable to demonstrate any advantage with off-pump CABG in terms of PLOS (Louagie et al, 2002; Haase et al, 2003; Gerola et al, 2004; Hravnak et al, 2004 Khan et al, 2004; Legare et al, 2004; Straka et al, 2004).

However, these findings are in contrast to other previous retrospective observational, case-matched and randomised studies suggesting that off-pump CABG is associated with a shorter PLOS than conventional CABG with cardiopulmonary bypass (Jones and Weintraub, 1996; Ascione et al; 2000; Lee et al, 2000; Ascione et al; 2001; Abu-Omar and Taggart, 2002; Berson et al, 2002; Cleveland et al, 2001; Plomomdon et al, 2001; Puskas et al, 2001; Van Dijk et al, 2001; Angelini et al, 2002; Magee et al, 2002; Järvinen et al, 2003; Puskas et al, 2003; Racz et al, 2004).

The non significant finding for cardiopulmonary bypass must be interpreted with caution since the use of cardiopulmonary bypass is at the surgeon's discretion and, with no set criteria for the selection of either procedure; the decision to use off-pump procedures may be more reflective of the experience and preference of the surgeon rather than individual patient variables. Furthermore, the referral and selection of patients for off-pump CABG surgery have evolved over time to include the elderly and female patients, and those with left main stem and multivessel disease (Mack et al, 2004). This makes comparisons with the earlier studies problematic because of changes in both the risk profile and the postoperative management of patients undergoing off-pump CABG and CABG with cardiopulmonary bypass. These factors may contribute to the differences reported in some of the earlier studies that were not replicated in this study.

It is evident from both the discussion of the univariate analyses and the literature reviewed that the variables identified as potential predictors interact in a complex fashion, with both each other and other variables, to influence PLOS and discharge within five days. It was not the aim of the analysis to establish causal relationships but to identify the existence of a relationship for the purpose of modelling predictions. Consequently, additional research is required to identify why any of the variables identified as potential predictors are associated with PLOS.

7.1.5 CONSTRUCTION OF THE PREDICTION MODELS

The 19 variables found to be univariately associated with PLOS and discharge within five days were subsequently hypothesised as predictors of these outcomes and entered into the multivariate analysis to develop models to predict PLOS and discharge within five days of CABG surgery.

Initially four models were developed: a model to predict PLOS with continuous variables preserved (model 1); a model to predict PLOS with continuous variables reduced to categorical variables (model 2); a model to predict discharge within five postoperative days with continuous variables preserved (model 3); and a model to predict discharge within five postoperative days with continuous variables reduced to categorical variables (model 4).

7.1.5.1 Models to predict postoperative length of stay

Models 1 and 2 identified eight predictors of PLOS; age, diabetes, ejection fraction, renal function, peripheral vascular disease, predicted mortality risk, marital status and index of deprivation. These findings are consistent with previous multivariate studies that have also identified these variables as important predictors of PLOS (Weintraub et al, 1989; Lahey et al, 1992; Paone et al, 1998; Aldea et al, 1999; Rosen et al, 1999; Peterson et al, 2002; Contrada et al, 2004; Anderson et al, 2006).

However, the limited ability of the models derived to predict PLOS suggests that although these variables are important, they are not the major determinants of PLOS. There was little difference in the predictive ability of models constructed with either continuous levels of measurement preserved or reduced to a categorical level. Models 1 and 2 could both only account for a small amount of the variation in PLOS at 11% and 12%, respectively. This finding was not unexpected as it is similar to that reported by others in the literature (Weintraub et al, 1989; Rosen et al, 1999; Peterson et al, 2002).

It is arguable that models that can account for this much variation in PLOS are not worthwhile since they provide little more discrimination than clinical judgement alone. However, the results also suggest that the current analysis, similar to previous analyses, failed to include one or more important variables that could improve the performance of the resultant models. As with all multivariate analyses, it is impossible to study all possible variables. Consequently the variables were selected for investigation based on prior empirical or theoretical support for an association with PLOS and entered into the multivariate analysis where there was support for an association by univariate analysis.

It is unlikely that an important clinical or physiological variable was not included in the current analysis as these have been extensively studied. However, psychosocial variables have been investigated to a much lesser extent. The identification of marital status and index of deprivation as important predictors of PLOS in this study highlights the importance of including psychosocial variables in any future analysis of PLOS.

Psychosocial variables may reflect the significance of the hospital admission for the disruption to the patient's social role and relationships, and as a result influence their motivation for discharge. Congruent with the theory of stress and coping, these variables may mediate the appraisal of impending CABG and the subsequent selection of coping strategies which in turn influence in-hospital recovery. The findings of this study thus suggest the potential for under-investigated psychosocial variables to explain some of the variation unaccounted for by this and previous models to predict PLOS. Further research attention should therefore be focused upon these variables.

Some aspects of PLOS will always be related to patient variables not included in the model or due to chance occurrences. PLOS may also depend on many variables that may not be related to the patient's preoperative profile including the referral criteria of community services, the experience and motivation of individual medical and nursing staff and their motivation to proactively plan and prepare patients for discharge, and organisational variables such as workload pressures that reduce the time available to proactively plan for discharge. Data on these variables is not easily measured or captured and is unlikely to be known preoperatively. This is primarily due to the organisation of care where staffing rotas change continuously and the high number of individuals involved in patient care, often for only a short time, throughout their hospital stay.

The difficulty of capturing and measuring such numerous variables means that the provider effect is rarely accounted for in such investigations. However, the current study included the organisational variables of hospital of surgery, consultant surgeon and the day on which the fifth postoperative day occurred, in order to investigate the variation due to these simplistic measures of within hospital variation or provider effect. None of these variables were identified as predictors PLOS, which means that the identification of the hospital characteristics that influence PLOS remains elusive.

Another reason why the models developed in this study may have accounted for only a limited amount of the variability in PLOS was that they were derived from only preoperative data. Previous research has shown that a large part of the variability in PLOS depends on events occurring in the postoperative period as well as practice variations both between and within hospitals (Weintraub et al, 1989; Rosen et al, 1999; Peterson et al, 2002). However, the scope of the current study and purpose of the models was to predict PLOS in the preoperative period so that this information could be used to plan patient care for individual patients and plan resources. Events occurring in the postoperative period may be of value for modifying the predicted date of discharge in the light of postoperative information in the postoperative period but they are of limited value for preoperative planning which was the stated aim of this study.

7.1.5.2 Models to predict discharge within five days

The models constructed to predict discharge within five days were able to account for much more of the variance in the outcome than models to predict PLOS.

Model 4, constructed with continuous variables reduced to categorical levels of measurement, performed better than model 3, with continuous levels of measurement preserved, accounting for 31% and 26% of the variance respectively. These results are comparable with the 29% reported Weintraub et al (1989) from their model to predict PLOS greater than ten days. The amount of variance accounted for by other logistic regression models has not been reported (Lahey et al, 1992; Lazer et al, 1995; Tu et al, 1995; Peterson et al, 2002).

Models developed from all 19 variables provided the most impressive classification results for the likelihood for discharge within five days and were selected for this reason. The effect of this decision is that the original stepwise selection method was the same as if the variables had been entered simultaneously, thus avoiding the well documented criticisms of the stepwise approach (Field, 2000; Lee, 2005).

Non-significant likelihood ratio tests and wide confidence intervals were obtained for many variables in these final logistic regression models which may have justified their removal in order to achieve more parsimonious models (Garson, 2008). However, the removal of non-significant variables negatively impacted upon the sensitivity (how well the model performed in identifying patients discharged within five days), overall classifications correct and the amount of variation explained by the models. However, specificity (how well the model performed in identifying patients discharged after five days), improved. Consequently, all the variables were retained in the final models in order to achieve the greatest amount of sensitivity as well as models that resulted in more overall classifications correct and could account for the greatest amount of variation.

The effect of reducing the threshold for classifying patients to the discharge within five days group showed the improved sensitivity that could be obtained from reducing the cut-off point to 0.4 and 0.3 but with corresponding poor specificity. This analysis resulted in a further seven models (models 5–11) being developed in order to re-run the models developed on all the cases for which data for the variables included was complete.

The percentage of patients discharged after five days that were incorrectly classified as PLOS of five days or less (a false positive result) increased with the 0.4 and 0.3 cut-off points. The 0.5 cut-off point was therefore retained due to the better specificity, improved overall performance and the potential utility of the model to discriminate between patients likely to achieve a five day discharge and those unlikely to achieve this aim.

Whilst the goodness-of–fit tests indicated that the logistic regression models had a greater than chance ability to predict discharge within five days, although models 3 and 4 correctly predicted only 55.4% and 56.2% of patients to be discharged within five days respectively. Neither model performed well as indicated by c statistics of 0.60 and 0.62 respectively. This compares negatively with 0.70 and 0.75 reported by Peterson et al (2002) from models developed to predict PLOS within five days and greater than 14 days respectively.

The models may not have performed well as a result of analysing incomplete audit data which substantially reduced the number of patients entered into the logistic regression analyses, resulting in insufficient power as well as an inadvertent selection bias. These issues are discussed later in the chapter.

The models were however, much better at predicting which patients would be discharged after five days, correctly predicting 79.7% and 83.3% respectively. The potential utility of this finding in practice is discussed in section 7.4 along with the possible implications for providing equitable patient care.

7.1.6 PHASE II: VALIDATION OF THE MODELS

The models constructed in Phase I were validated on another cohort of patients in Phase II of the study.

Validation of models 1 and 2 showed no difference in the distributions of predicted PLOS and actual PLOS but the performance of these models were such that their clinical utility was negligible. The performance of models 3 and 4 in the validation sample was also poor. The ability of these models to correctly classify patients into the two discharge groups, as measured by the area under the ROC curve, showed that the models performed little better than chance with c-statistics of 0.57 and 0.55 respectively.

The hypotheses that PLOS and discharge within five days of CABG can be predicted from one or more of the preoperative patient variables included in the study (hypotheses 3 and 4) were rejected given the performance of the models in both the development and validation samples.

The theoretical framework of the study emphasises individual differences in the way patients respond to CABG which may account for the poor performance of the models to predict either PLOS or discharge within five days. Within the person-situation transaction, the person's coping style is viewed as a function of their perception of the circumstances, their personality and their past history of coping. So whilst variables such as age, gender, mortality risk category or marital status may be associated with PLOS or discharge within five days, there may have been as much variation within these groups as there was between the groups. Thus, this may explain why although these variables were univariately associated with PLOS, or discharge within five days, they were not good predictors of these outcomes. The combined effect of these variables was therefore found to be minor.

The contribution of any of the individual variables in the models constructed to predict PLOS or discharge within five days is difficult to determine as each depends on the other variables in the model. However, it was not within the scope of the current study to investigate or determine the pathways by which individual variables influence PLOS but to analyse the combined influence of multiple variables on PLOS and discharge within five days of surgery for the purpose of predicting these outcomes preoperatively.

There are other possible reasons why the models did not validate well in Phase II. The timeframe between Phase I and Phase II was quite short with no major advances or changes to care between the two phases. However, major unforeseen changes to the geographical location of referrals between the two phases mean that the models may therefore have been validated on a different population to the population from which they were developed.

Despite the change in some referrals for CABG, from Essex in Phase I to counties in the south west of England in Phase II, the characteristics of the samples in Phase I and Phase II were generally comparable. However, the potential impact of the further travel involved for patients and their families or the need for families to stay in temporary accommodation in London in Phase II is unknown. This may have affected the ease of visiting arrangements for wider family and friends and been more inconvenient and disruptive to their lives than if the patient had attended a local hospital. This may therefore have potentially influenced their motivation for discharge in either direction.

The change in referral pattern illustrates the evolving nature of the models as both the characteristics of the population and wider changes in healthcare over time may alter the relative importance of some variables. For example, the introduction of payment by results and the 18 week target from general practitioner referral to hospital treatment by 2008 (Department of Health, 2004b) has placed greater emphasis on increasing patient throughput and waiting times have officially fallen dramatically as a result. Waiting times continued to decrease over the course of the study, potentially altering the relative importance of this variable.

Of course, proactive discharge planning may have affected the performance of the models as all patients were informed of an expected PLOS of five days. The failure to account for within-hospital variation such as staffing and workload differences may also explain the poor discriminatory ability of the models.

7.1.7 PERCEIVED STRESS AND HEALTH LOCUS OF CONTROL

The influence of perceived stress appraisals and health locus of control on

PLOS and discharge within five days were also evaluated in Phase II. Consistent with the theory of stress, appraisal and coping (Lazarus and Folkman, 1984), it was hypothesised that the way in which impending CABG was perceived and appraised would influence behavioural aspects of the patient's recovery that would be reflected in their PLOS or likelihood of discharge within five days of surgery.

However, the results of this preliminary univariate analysis of both perceived stress and health locus of control did not support the hypothesis that the assessment of either of these psychological variables could help in the prediction of either PLOS or the identification of patients likely to be discharged within five days of surgery.

An alternative explanation is that these psychological variables did influence PLOS and discharge within five days but the direction and magnitude of the effect was subject to individual differences thus resulting in the non-significant findings reported. For example a high perceived stress score may have facilitated the "work of worrying" for one patient and the subsequent selection of a problem-focused coping strategy and therefore a shorter PLOS. However, the same score may elicit an emotion-focused response in another patient and therefore result in longer PLOS.

The direction and magnitude of the effect may also have been dependent on or mediated by other unstudied variables. For example, a high perceived stress score may only have increased PLOS when perceived social support was low or may have been mediated by their self-esteem.

Further investigation of the selection of coping strategies and variables theorised to influence perceived stress such as social support and self-esteem (Lazarus and Folkman, 1984) is therefore required in order to fully evaluate the potential contribution of stress appraisals and feelings of control to the prediction of PLOS and discharge within five days of CABG.

According to Lazarus and Folkman (1984) the appraisal process is influenced by many variables. However, analysis of the differences between stress appraisals and feelings of control, with the characteristics of the local CABG population showed that none of the variables studied were associated with perceived stress for patients in the preadmission clinic prior to CABG as measured using the Perceived Stress Scale (Cohen et al, 1983).

Again, this finding may have reflected individual differences within the groups. However, the non-significant findings of this study for both perceived stress and health locus of control must be interpreted with caution due to attrition and the use of single instruments to measure these variables. Consequently, there are a number of methodological problems that must be addressed before such data can be interpreted with confidence.

7.1.7.1 Attrition

The data was collected for only a small percentage of patients (13%) in Phase II of the study. There were various reasons for this low response rate including the fact that 46.5% (n = 234) of the sample did not attend preadmission clinic, 8% (n = 40) had attended preadmission clinic before the data collection period and were therefore not eligible, 10.3% (n = 52) were not invited to participate due to an administrative error, and 22.7% (n = 109) declined to participate, did not return their questionnaires or were not given the questionnaires for any reason. The attrition rate of eligible patients was 62.1% for the PSS, and the chance and powerful others items of the MHLC scale, and 61.6% for the internal items of the MHLC scale.

Sample size

The subsequent small sample size may have resulted in insufficient power to detect univariate relationships between the psychological variables and PLOS or discharge within five days of CABG. Retrospective power calculations for the sample size of 67 achieved for apprised stress indicated that the analyses were sufficiently powered to detect medium sized effects for PLOS but not discharge within five days. The sample size was clearly below that calculated in advance for the multivariate analyses if the univariate results had been significant.

Selection bias

For patients admitted for non-elective surgery, preadmission assessment did not take place. The influence of stress appraisals associated with non-elective admission was therefore not evaluated in the current study and created a selection bias towards patients undergoing only elective surgery who were also more likely to be younger, male, married and not living alone. Further investigation should therefore endeavour to include all patients undergoing CABG in the defined time period rather than just those attending preadmission clinic in order to minimise such a selection bias.

However, it is very unlikely that patients admitted for emergency or salvage CABG will be able to complete psychological questionnaires in the preoperative period in any study. The impact of preoperative stress appraisals for this group of patients is therefore likely to remain unknown. It is, however, feasible that patients admitted for urgent surgery may be included in future investigations, although this will depend on their ability to independently complete the questionnaires.

Maximum 100% recruitment is almost impossible to achieve with preoperative patient-reported measures and, as demonstrated in this study, there is likely to be a relationship between recruitment and the severity of illness which is likely to result selection bias in favour of patients undergoing elective surgery. In addition, a small percentage of patients are likely to be lost at the outset due to language, literacy and cognitive issues, and there is variation in the willingness and competence of local staff to administer questionnaires. A fully funded research team would therefore be required to address these issues in any further study.

7.1.7.2 Additional Measures

The psychological concepts might also have been better characterised if additional instruments to measure these had been used, and these had been used at several time points antecedent to CABG.

Other measures of patient stress might include physiological measures such as cortisol levels or other self-report questionnaires. Repeating such measures throughout the preoperative period is also important since variations in the stress experienced by patients may vary during this time.

In accordance with the theoretical framework, perceived stress is likely to vary over time as the patient makes continuous appraisals and reappraisals of the changing person-environment relationship. Hence, stress appraisals may have changed as the preoperative information given at the time of preadmission was used in the patient's secondary appraisal of the impending event, and before the patient completed the questionnaires. It may be that the average stress score over the preoperative period, or the stress score a one key point is important but without multiple measures, this question is not answered by the current study.

Consequently, further research on a larger sample which includes all elective patients and those referred for urgent CABG, using additional instruments at different time points, is required in order to comprehensively evaluate the potential importance of stress appraisals and feelings of control for the prediction of PLOS and discharge within five days of surgery. The non-significant findings this initial investigation remains tentative until the results are confirmed by such study.

7.2 METHODS

The discussion now focuses on the research design, sample, data collection and analysis and the implications of the methods selected for the internal and external validity of the findings.

7.2.1 Research Design

An observational approach was used for the development and validation of the predictive models over two phases. The models were developed retrospectively from a cross-section of the population in Phase I and validated prospectively on another cohort of patients in Phase II.

7.2.1.1 Observational approach

An observational approach was selected for several reasons including; the current stage of research in this field, the ethical problems of assigning patients to discharge groups without a firm research base, and the advantages afforded by observing a large number of patients in their natural setting.

Prior to this study, the multivariate prediction of PLOS and discharge within a defined period had remained elusive despite considerable research attention. However, the failure of previous studies to investigate psychosocial variables represented a gap in the current understanding of this topic for which data was not available. This lack of knowledge meant that it would have been unethical to select an interventional design at this stage of the investigation. Data from further exploratory multivariate study which included the psychosocial variables was required before any interventional study in which patients would be allocated to a protocol could be justified.

An important strength of the observational research design selected for this study was that it allowed the integrity of the context in which care was provided to be maintained. Exploratory data was collected on the combined influence of the psychosocial and traditionally studied variables of interest as they naturally occurred in the individuals studied, free of any bias or influence imposed by the conduct of the study.

A observational research design was therefore was considered by the author to be the most suitable approach to address previous gaps in the investigation of the research question and enable the collection of data on naturally occurring variables from which new knowledge could be generated. All previous multivariate analyses of PLOS, as reviewed in chapter 4, have also used observational methods although their reasons for doing so are not explicit.

7.2.1.2 Cross-sectional and cohort design

Retrospective cross-sectional methods were selected for Phase I of the study and the identification of potential predictors. In Phase II, a cohort design was selected to prospectively test the effectiveness of these variables to predict PLOS and discharge within five days.

These designs complemented the observational approach as neither required random assignment and together they facilitated the study of a large number of patients by a single researcher. This provided the study with high power to detect differences and favourable external validity by enabling the collection of exploratory data from a large sample of patients who were representative of the wider CABG population as advocated by Black (1996).

These methods are congruent with the stress and coping framework used to conceptualise the research situation. The transactional theory of Lazarus and Folkman (1984) has been described as suited to both cross-sectional and cohort research designs (Shaw, 1999). However, because cross-sectional designs provide a 'snapshot' of the situation, the study did not examine the bidirectionality of the associations between the variables which is central to the theory of stress, appraisal and coping (Lazarus and Folkman, 1984). This was not a problem for the study because the aim of Phase I was simply to identify those variables that influenced PLOS and not to examine the bidirectionality of the associations between the variables identified.

The cohort design selected for Phase II was a suitable method to prospectively test the effectiveness of the variables identified in Phase I in a different sample and also to analyse and evaluate the potential contribution of stress appraisals and feelings of control to the prediction of PLOS and/or discharge within five days. As the patients were selected before PLOS and discharge within five days was observed, the effect of each variable in the models was calculated before these actual outcomes were known and then compared.

The cohort design was also suited to both the secondary and primary data collection methods employed in this phase of the study. Data on stress appraisals and feelings of control were not available for any of the patients in either phase of the study because this information was not routinely collected. This data was therefore collected prospectively by the researcher during the preoperative period for the Phase II cohort and the patients then followed-up postoperatively until discharge.

7.2.2 SAMPLE

A convenience sample of the local CABG population was selected for both Phase I and Phase II. The samples for both phases were described as convenience samples in so far as they were drawn from parts of the population that were readily available and accessible to the researcher.

The use of single-centre convenience samples of consecutive patients reflects the widely used current practice in this research setting. This method has obvious advantages in terms of cost, time and logistical concerns but it was also optimal to address the aims of this study.

7.2.2.1 Single-centre study

The use of a single centre reflected contemporary, relatively consistent practice patterns on PLOS in the population of interest. As a total population sample of the local CABG population, the sample was representative of this population over one year and accounted for possible seasonal variations in the characteristics of this population.

Only the local influences on PLOS at the study centre were investigated in the current study because this was consistent with the aim to develop local prediction models. The development of local procedure-specific models was considered by the author to be the most appropriate approach to the research question given that the case-mix between centres is known to vary (Keogh and Kinsman, 2004). The heterogeneity of the wider population thus provided justification for the local risk-modelling approach adopted in this study.

Similarly, the development of models to predict discharge within five days reflected a locally relevant cut-off point that may not be of equal importance or interest at other centres, or in the future. Discharge with five days of CABG reflected local contemporary practice at the Trust as documented in the integrated care pathway used at the study centre and so was a clinically relevant cut-off for this investigation. Previous studies have similarly defined short and long stay depending on their motivation for research and cut-off points pertinent to their study population and healthcare system such as diagnostic group limits (Weintraub et al, 1989; Lahey et al, 1992; Lazar et al, 1995; Tu et al, 1995; Mounsey et al, 1995; Peterson et al, 2002).

7.2.2.2 Sample size

The selection of a convenience sample of consecutive patients allowed samples of sufficient size, as calculated in chapter 5, to be obtained for both the development and validation of the models within a relatively short timeframe. These factors justified the selection of the non probability sampling method used in the current study.

The alternative use of a probability sampling method would have lengthened the time taken to obtain samples of sufficient size, and the subsequent issue of temporal variations, such as staff turnover and changes to practice, over this longer time period may also have become problematic.

The small sample size (n = 68) that was achieved for the investigation of perceived stress and health locus of control in Phase II of the study was problematic. This was partly due to a substantial decrease in the number of patients attending preadmission clinic during this period which occurred as a result of the opening of a cardiac surgery unit nearby that redirected local referrals away from the Trust. Consequently, more referrals were accepted from hospitals further away and these patients did not attend preadmission clinic which impacted upon the number of patients available for psychological assessment in the allotted time. It was not logistically possible to include these patients in the study because their first contact with the study centre was usually on the afternoon before the day of surgery and their participation in the psychological assessments would have impinged upon the time available for medical and nursing assessment and preoperative preparation.

A total of 269 (53.5%) patients attended preadmission clinic, of which 40 attended before the data collection period and were therefore not eligible. A further 52 potential participants were not invited to participate because the researcher was unable to collect data on psychological variables for the first month of the data collection period due to a delay in the receipt of ethical approval documentation. However, due to the time scale of the study, extending the data collection period was not feasible.

The characteristics of the sample of patients who did complete the psychological assessments indicated that this sampling method had also resulted in a selection bias of younger and lower risk patients when compared to the remaining sample of patients in Phase II who did not participate in the psychological assessments. It is therefore evident that this sub-sample was not representative of the total sample in Phase II and, as a result, the non-significant findings for the psychological variables cannot be generalised beyond this smaller study sample.

This bias was expected because the sampling method naturally excluded non-elective patients who did not attend preadmission clinic. Selecting elective patients who did attend preadmission clinic did, however, allow the exploratory data for the psychological variables to be collected with minimal inconvenience for the patient. This time is also more conducive to explaining the study and obtaining informed consent to participate than on actual admission when preoperative preparation becomes paramount.

7.2.2.2 Excluding deaths

Patients who died in the base hospital on the same admission as surgery were excluded from the analysis on the basis that mortality may artificially shorten PLOS if not excluded (Rosen et al, 1999). Indeed, this was the case in the current study where the range of PLOS was considerably less for patients excluded from both the Phase I and Phase II samples because they died (0-42 days and 1-65 days respectively) compared to those included (3-242 days and 3-105 days).

As expected, a comparison of the characteristics of those patients included in the study with those who were excluded because they died showed that more patients with accepted mortality risk factors were excluded from statistical testing. Those patients who were excluded were more likely to have undergone non elective surgery, have a smaller body size, suffered from renal disease, poor ejection fraction, and pulmonary disease and have a higher mortality risk score. The decision to exclude patients who died in hospital thus resulted in a selection bias since these variables have been shown, in varying degrees, to increase PLOS as well as mortality as outlined in chapter 3.

Authors of previous studies have not always been explicit as to whether they have excluded deaths when describing the distribution of PLOS in their samples. They also rarely report the results of any comparison between patients included and excluded from statistical testing. This makes comparisons between the current study and previous studies problematic as it is not clear if like is being compared with like in this respect. Explicit details of the decision to exclude patients who died, and the comparison of the characteristics of the resultant samples with the original samples, are therefore strengths of the current study which provide greater insight into this area of research.

7.2.3 DATA COLLECTION

The study utilised two sources of routinely collected data; data contributed to the SCTS database and the electronic patient record. This avoided unnecessary duplication since suitable data required for the study had already been collected. In addition, because data from both sources was collected independently of any hypotheses and by people other than the researcher, this diminished the opportunity for observer bias.

Economical and ethical considerations further justified the use of secondary data. The existing data sources enabled the researcher access to an extensive data set that enabled a large number of patients and variables to be observed inexpensively within a relatively short timeframe. This was therefore an effective and efficient use of resources. It also maximised the utility of previously collected data as well as the efforts of both the patients and those responsible for recording the data.

Whilst this method of data collection is versatile and less costly than primary data sources, the secondary analysis of data retrospectively retrieved from a large audit database of patient-identifiable information has inevitable limitations and implications. These limitations include; the suitability of the data to answer the research question, the failure to collect data on an important variable, the quality of the data, and the ethical implications of using patient-identifiable audit data without consent. The extent to which these limitations affected the current study is now discussed.

7.2.3.1 Suitability of the data

Whilst it is acknowledged that the data used in the study was not collected for the purpose of the research (with the exception of the psychological questionnaires in Phase II), the data largely addressed the research question. Data for all the variables identified within the literature review as important in the investigation of the research question were available within the two sources of data used.

The use of such data was, however, limited to the variables and definitions for which the data was originally collected. The SCTS database did not include data on the following important variables; marital status, living alone, employment status, date the patient went onto the waiting list, date of admission and discharge, and also the psychological variables. This limitation was identified by the researcher following the literature review and data for these variables were subsequently either retrieved from the electronic patient record or prospectively collected by questionnaires in Phase II.

Socioeconomic variables

Socioeconomic variables were also not included in the database. Instead, an overall deprivation index based on multiple domains was calculated based on the patient's postcode (ID2004). This was broader than the material conceptualisation of deprivation used previously by Taylor et al (2003).

An advantage of using this index was that the patient's postcodes were all readily available in the SCTS database meaning that these could be calculated for the majority of patients in the study. Although a small number of newer postcodes were not recognised, the index of multiple deprivation is periodically updated with the ID2007 being recently published (Noble et al, 2008).

A disadvantage of this aggregate approach is that an area measured as relatively deprived by the index may contain large numbers of people who are not deprived and vice versa (Office of the Deputy Prime Minister, 2004). Making assumptions about individuals based on aggregate data for a group is thus vulnerable to the "ecological fallacy". The index is also dependent on the sources of data used within each domain which may limit the robustness of ID2004 as an index of deprivation.

Despite these disadvantages, the use of an area-based aggregate approach to measuring deprivation offered the most economical and feasible method to capture the complex combination of social and economic circumstances of each of the individuals studied in the current study. This allowed the potential importance of this variable for the prediction of PLOS to be investigated for a large number of patients without additional expense or inconvenience for the patients studied. It is possible that collecting supplementary data for each patient such as income, occupational group or educational attainment may provide fuller information about the socioeconomic circumstances of the individual in order to assess the extent of deprivation. However, the extent to which this is feasible and justifiable is debatable in terms of cost and inconvenience and may be perceived as intrusive and unnecessary by patients. Evidence of the value of collecting this supplementary data was therefore first required.

7.2.3.2 Possible failure to collect data on an important variable

A thorough and comprehensive search of the literature was undertaken to identify important variables for the investigation. The selection of variables was also theoretically underpinned by the theory of stress appraisal and coping (Lazarus and Folkman, 1984). This minimised the possibility of failing to include an important variable and resulted in the selection and univariate investigation of 30 empirically or theoretically identified preoperative variables.

The study specifically focused on the prediction of PLOS in the preoperative period. This is because predicting PLOS in the preoperative period has a much greater practical utility for all concerned in terms of planning. In the postoperative period the discharge date is reviewed daily based on actual clinical and social information and so predictive tools are of much less value at this time.

Relevant to this aim, the literature review focussed on the identification of potential predictors of PLOS that are known in the preoperative period. It did not include the influence of perioperative and postoperative variables or other outcomes, such as intensive care unit stay, that have been included by previous researchers (Weintraub et al, 1989; Lazer et al, 1995; Tu et al, 1995; Mounsey et al, 1995).

A broader approach which included perioperative and postoperative variables would have identified other potentially important predictors of PLOS which may account for a large amount of the variability in this outcome. However, the narrower focus on preoperative variables was maintained in line with the stated aims of the study and the endeavour to develop prediction models with the greatest potential clinical and practical utility within a multidisciplinary environment.

It is acknowledged that other potentially important preoperative variables may not have been included in the study because the data was not available, the information was not easily quantified or captured, or for practical and ethical reasons. This is a particular issue for hospital variations and psychosocial variables.

Between and within-hospital variation

It is recognised that healthcare providers are an important influence on PLOS. Peterson et al (1999) calculated the provider effect to account for 40% of the variation in PLOS. However, the actual characteristics that influence PLOS both between and within hospitals have yet to be identified or investigated.

As a single-centre study, between-hospital variations were not investigated in this study. However, for some time, research has associated the volumes of CABG procedures conducted by a hospital with mortality and cost outcomes (see for example Hannan et al, 1991; Saleh et al, 2009). In such studies, the volume of CABG procedures has been used as an indicator of quality. It has been argued that procedure volume may also be a proxy for other hospital characteristics such as processes of care, expertise of staff and ratios of staff to patients (Elixhauser et al, 2003). Based on the findings of these studies of hospital characteristics and other outcomes after cardiac surgery, the author suggests that, in the absence of information related specifically to hospital characteristics and PLOS, the following variables should be investigated in any future between-hospital analysis: the size/number of beds, volume/number of procedures, teaching status, staffing levels/nurse-to-patient ratio, location, and use of patient transfer and discharge protocols.

Within-hospital variation, such as staff variations in proactively preparing patients for discharge, the availability of beds for patients discharged to other hospitals, the admission requirements of convalescent homes, and the reduced services available at weekends and on bank holidays also cannot be accounted for in the current study. This was because, in reality, within-hospital variations such as these were virtually impossible to capture in any analytically meaningful way because they are subject to constant variation that may be indirectly influenced by many factors, and many members of staff may be involved in the provision of care, some for only very short time periods.

Psychosocial variables

There are a plethora of psychosocial variables that could have been investigated such as the patient's perception of social support or personality type. However, data for these variables are not routinely measured and collected also, and probably as a result, these have been neglected in previous studies of PLOS meaning there was a lack of empirical support for their inclusion in the current study.

However, only those variables with empirical or theoretical support of an association with PLOS after cardiac surgery were selected in order to achieve a balance between not omitting an important variable and conducting a purposeful investigation. Limiting the number of variables in this way also minimised the possibility of obtaining spurious results due to the random effects of many variables, and served to limit the sample size required (Field, 2000).

There must also be sufficient justification for the collection or use of existing patient data for this to be ethically plausible, particularly given the cost, and potential inconvenience involved in collecting that data. Patients and staff may also perceive such questions as superfluous or even an invasion of privacy.

Consequently, new knowledge regarding these other potentially important psychosocial variables was not made available as a result of the current study. Whilst it may be desirable to measure multiple baseline psychological variables, the decision to collect additional data for just two theoretically identified psychological variables was justified in order to minimise the time and inconvenience of measuring these variables for both staff and patients during this initial exploratory investigation.

7.2.3.3 Quality of the databases

The use of the SCTS database and electronic patient records assumed that these records were accurate, reliable and complete. Misclassification errors, subjective interpretations, variations in coding practice and incomplete coding are all limitations of the secondary analysis of data approach (Ferraris and Ferraris, 2003).

Society of Cardiothoracic Surgeons' database

The quality of data collected for contribution to the SCTS database in terms of the source of data, the methods used for data collection, standardised definitions, and data reliability were all evaluated in chapter 5 and deemed by the author to be of acceptable reliability and validity. In addition, a joint external assessment of the completeness and validation of data collected by the study hospitals for contribution to the SCTS database, based on 2004 data, deemed this to be better than that collected nationally (Central Cardiac Audit Database and Society of Cardiothoracic Surgeons, 2005).

Data used in this study was also more complete than data collected nationally for the following variables retrieved from the SCTS database: age, body surface area, body mass index, diabetes, hypertension, renal disease, ejection fraction, peripheral vascular disease, Parsonnet score, EuroSCORE and urgency of surgery.

Electronic Patient Record

The electronic patient record is generally completed by many individuals but is usually checked for accuracy and completeness at key time points such as at referral, booking, preadmission and on admission to hospital. Data used in the current study was moderately well recorded for the following variables retrieved from the electronic patient record: ethnic group, living alone, marital status. However, the official date of going on the waiting list was altered when a patient was admitted and discharged before surgery, for whatever reason, and then readmitted for surgery at a later date. Where this occurred, the official date of going on the waiting list changed to the date of discharge from the initial admission but to avoid contaminating the data in this way, the original waiting list date was retained in this study.

Missing data

Completeness of the data was a weakness of both sources of data for some variables. Analysis of where the missing data occurred showed that this was not missing at random. Missing data retrieved from the electronic patient record was concentrated in the variable of employment with data missing for 50.3% of patients. Missing data retrieved from the SCTS database was concentrated in the following variables: previous myocardial infarction (29.1%), dyspnoea (29%), angina (28.9%), left main stem disease (33.5%) and smoking history (29.5%).

Missing data from both sources contributed to the reduced number of complete cases available for the logistic regression analyses. As a result, the adequacy of these sources of secondary data to answer the research question was limited in this respect. Elective patients were more likely to have data recorded for all variables and were therefore more likely to be included in these analyses than non-elective patients. Similarly, patients who lived with their spouse or next of kin were more likely to have their living arrangements recorded than those who did not and therefore more likely to be included in the analyses.

The variables in which the data was missing are generally more easily assessed in the preoperative period for elective patients. Given the relative urgency of the surgery required for the non-elective patients, less time may be available for this data to be routinely collected and recorded. Missing data from the electronic patient record was concentrated in non-elective patients resulting in a selection bias towards elective patients. However, missing data from the SCTS database did not result in a selection bias.

Missing data could have been minimised with a prospective research design in which missing data was collected by the researcher for the purpose of the study. However, most preoperative clinical data would not be available for non-elective patients given the urgency of their operation. Data missing for this reason was therefore unavoidable and future analyses should, for this reason, consider developing separate models for elective and non-elective patients.

Development of audit databases

Whilst the limitations of utilising secondary data have been acknowledged, data collected routinely in the preoperative period and as part of the audit process has provided high quality data of acceptable validity and reliability for a large sample of patients that would otherwise have been beyond the resources of a single researcher.

The growing improvement in coding practice and audit activity has been driven by the continuing shift towards evidence based practice, more informed consent for patients and the increasing interest in resource related issues which means that databases are an increasingly valuable and economic source for health research (Black, 1996; Keogh and Kinsman, 2004). The SCTS database has developed considerably over the last decade and is therefore likely to provide more and better quality data for research in the future.

Currently, all NHS hospitals in the UK are expected to contribute to the collection of comprehensive and standardised data to enable a greater understanding of changing trends within the cardiac speciality and comparison of clinical performance with national and international standards. Whilst missing data for non-elective patients remains a concern, data quality is expected to improve considerably. Ongoing measures to harmonise cardiac data collection include the use of recommended datasets and mechanisms for online, real time data submission and viewing so that a patient's progress can be tracked and additional procedures flagged, thereby providing more accurate information on re-interventions at other hospitals (Keogh and Kinsman, 2004).

Whilst the demand for data collection and audit activity has grown as part of wider changes in the NHS, the suitability of audit data to answer a research question remains subject to debate (Closs and Cheater, 1996). Many authors have sought to draw distinctions between audit and research but there has been growing recognition that the two are interrelated in a variety of ways in a relationship that is both symbiotic and ultimately synergistic (Black, 1992; Smith, 1992; Firth-Cozens and Ennis, 1995; Closs and Cheater, 1996; Mead et al, 1996; Wilson et al, 1999). It has been identified that one of the ways in which research and audit are interrelated is the use of existing high quality data and that audit can provide high quality data for non-experimental evaluative research (Black, 1992, Closs and Cheater, 1996; Wade, 2005).

Data for the electronic patient record is recorded by many diverse health workers during the hospital episode and is therefore subject to large variations in practice and also a lack of the use of standard definitions. The quality of this source of data was therefore potentially questionable in terms of validity and reliability as well as completeness. In retrospect, data on the variables retrieved from this source would perhaps have been better collected prospectively by the researcher or, in future, incorporated into the SCTS database if this data source is to be more valid and complete. At the time of the study, the control of the variables that were entered onto the SCTS database within the Trust was not something that the researcher would necessarily have been able to influence. However, empirical support provided by this study may influence future decisions.

7.2.3.4 Using patient-identifiable audit data without consent

Upon retrieval, the patient-identifiable data used in the current study was immediately anonymised to protect the patient's right to privacy and then encrypted to minimise the risks to the security of the information. Permission to use the data in this way was granted by the Lead Clinician and the study was registered with the Caldicott Guardian of the study centre. Approval from the local research ethics committee approval was also granted.

Informed consent was not obtained from each patient because this would have been a major logistical challenge which may have resulted in a low recruitment rate and possibly introduced a selection bias if patients had been excluded from the study because they did not consent. Both these factors would have reduced the external validity of the study findings.

The secondary use of patient-identifiable information within the NHS for research purposes without prior consent is a contentious issue that raises important ethical questions. Changes to both UK legislation and professional guidance in order to safeguard the patient's right to privacy reflect the impact of the advances in technology and the risks to the security of patient information posed by electronic records and data handling in the NHS, primarily in the form of The Data Protection Act (1998).

Ideally, patients in a research study should have given their consent to the use of data that should not identify them, but the balance between protecting the confidentiality of patients and facilitating research has stimulated much debate (see for example Doyal et al, 1997; Walton et al, 1999; Al-Shahi et al, 2005). Many have agreed that informed consent is unnecessary and impractical when using previously collected anonymised data in observational studies that could affect the methodological integrity of the research and result in flawed studies with invalid findings (Walton et al, 1999; Al-Shahi and Warlow, 2000; Roberts and Wilson, 2001; Evans and Ramsey, 2001; Willison et al, 2003; Dawson, 2004; Fox, 2004). This view is consistent with the advice of the Patient Information Advisory Group (Patient Information Advisory Group, 2008), now replaced by the National Information Governance Board for Health and Social Care.

7.2.4 Statistical Modeling

The models were constructed by applying statistical modelling techniques to the data. In the absence of a statistical modelling technique that perfectly fits the data collected, the selection of statistical model was based on their ability to fit the data and how well their assumptions were satisfied by the data. Where possible, the limitations of applying the models to the data were addressed although it is acknowledged that the models may have been more stable if the data had fully met the assumptions of the statistical models used.

7.2.4.1 Postoperative length of stay

The generalised linear model multivariate ANOVA was selected based on the superior performance of this modelling technique to predict PLOS after CABG when compared to other models (Austin et al, 2002). It has been demonstrated that the choice of statistical modelling technique influences the variables that are found to be statistically associated with PLOS after CABG surgery (Austin et al, 2002). The variables identified as important predictors of PLOS in this study are therefore influenced by the selection of this statistical modelling technique.

The assumptions of multivariate normal distributions, linear relationships and equal variances for each variable were not met for the modelling of PLOS. The multivariate ANOVA is generally robust to violations of the assumptions of normality and equal variances between the groups but it is sensitive to the presence of outliers. For this reason, outliers with a PLOS greater than 12 days were excluded to improve the symmetry of the distribution and the performance of the technique.

7.2.4.2 Discharge within five days

Binary logistic regression was used to predict the probability of discharge within five days. This is a widely accepted statistical modelling technique to explore the relationship between predictor variables and a categorical outcome that has been used in previous CABG studies (Weintraub et al, 1989; Tu et al, 1995; Peterson et al, 2002; Anderson et al, 2006).

The assumptions of linearity in the logit and additivity for the use of logistic regression are more likely to be violated as the number of variables and the subsequent number of possible interactions increase (Lee et al, 2005). Consequently only variables identified as associated with discharge within five days of surgery by univariate analysis were included in the logistic regression analysis in order to limit the number of variables entered into the models and thus reduce the likelihood of violating these assumptions.

7.2.4.3 Stepwise methods

The study employed stepwise methods to discover relationships between the variables. Stepwise methods are recommended for use in the exploratory phase of research in which no a-priori hypotheses regarding the relationships between the variables are made and are generally considered to be the most robust of the techniques to use to identify variables with statistically significant effects for inclusion in regression models (Menard, 1995; Tabachnik and Fidell, 2001).

Stepwise methods can be subject to criticism in that they are influenced by random variation in the data and seldom give replicable results even if the models are retested within the same sample (Field, 2000; Lee, 2005). In this respect, the power to detect important variables is limited and further validation is required. The variables in the final models, and the size of the coefficients, were dependent on the data set that was used in Phase I and for this reason were validated using another data set in Phase II.

Multi-collinearity among the variables can also result in large standard errors that mean the correct estimate of the independent effects of the variables was not obtained (Ostir and Uchida, 2000). However, examination of the variance inflation factors showed that multi-collinearity was not a problem for any of the variables in the models so this was unlikely to be the case.

7.2.4.4 Statistical modelling techniques

In general, statistical modelling techniques tend to provide good predictive power for groups of patients. Models such as those developed in the current study are therefore particularly useful for service planning at the population level and for resource planning within hospitals.

Statistical models tend to be less satisfactory for individual patient outcomes. Dupias (2005) has argued that predictive risk models do not provide much more discrimination than clinical judgement alone. However, whilst using such models to predict individual outcomes may be difficult to apply at the bedside, they can offer guidance on the probability of an event occurring given the preoperative variables included within the model.

It is acknowledged that the statistical models constructed in this study are an approximation to the manner in which PLOS and discharge within five days of surgery depend on other variables. Such models are in constant evolution and no single model will ever perfectly measure the intended outcome or can ever be termed the correct model (Collet, 1991). Predictive models also require periodic recalibration as patient care advances and the characteristics of the population change, potentially limiting the timeframe of their usefulness.

The strengths and weaknesses associated with all the methods selected in this study have inevitable implications for the internal and external validity of the findings.

7.2.5 Internal Validity

Internal validity refers to the extent to which the effect on the dependent variable can be attributed to the independent variables studied. Internal validity is achieved when the effect on dependant variable can only by attributed to variation in the independent variable(s).

Observational retrospective studies are subject to a number of inherent threats to their internal validity which limit the extent to which the outcomes observed can be attributed to the variables studied. These include; the selection of patients, the failure to achieve a homogenous distribution of variables between groups, a lack of control for confounding variables, and the inadvertent failure to collect data on an important variable (Ferraris and Ferraris, 2003; Boslaugh, 2007). It was not the aim of the current study to establish causal relationships between the variables but several measures were taken to counter these threats and ensure their impact was minimised.

7.2.5.1 Selection of Patients

In order to minimise the possibility of a selection bias a total population sample of all patients who underwent first time isolated CABG at the study centre between the dates specified was selected. Data was collected over one year, which was considered by the researcher to be sufficiently long enough to account for any local variations in referrals and practice, and also to obtain a sufficient sample size.

The exclusion of patients who died in the base hospital on the same admission of surgery resulted in the loss of only 14 patients (1.3%) from the study. There was some differential loss of participants from the study for this reason since those who died were a higher risk group as measured by Parsonnet and EuroSCORE but they were otherwise generally comparable in terms of age and gender. The characteristics of those patients included in the study were also comparable with the national CABG population. This equivalence preserves the internal validity of the study.

Missing data for some variables was a problem which resulted in some groups being more likely to be excluded from the analyses as previously discussed. This differential loss of participants is acknowledged as a threat to the internal validity of the study.

7.2.5.2 Failure to achieve a homogenous distribution of variables between groups

The variables in the study were observed as they naturally occurred. However, the resultant non-equivalence of the groups makes it difficult to conclude that any differences in PLOS and discharge within five days were due to the variable of interest. For example, patients in the oldest age group also had the largest proportion of female patients, widowed patients, and patients living alone. Similarly, age, living alone, being widowed and diabetes was unequally distributed across the gender groups. The extent to which these variables varied with each other confounds their independent effects on the outcomes measured.

7.2.5.3 Lack of control for confounding variables

It is recognised that the lack of control in observational studies for confounding variables makes it difficult to attribute the outcomes measured to the variables studied. This causes difficulty in making an unequivocal decision about the independent effects of the variables studied because alternative explanations for the outcomes observed cannot be ruled out.

Where evidence of an association between a variable of interest and PLOS or discharge within five days was found, this did not necessarily prove causation. It may have reflected the independent variable was influencing PLOS but alternatively, it may have reflected the fact that both the associated variables were themselves affected by a third, unstudied variable.

Where there is strong empirical support of an association between the variable of interest and the outcome measured in the findings of previous studies this assists in the interpretation of the results and decisions about ruling out alternative explanations. Consequently, the findings of the current study have been compared to previous study findings, where available, to aid the interpretation of the independent effects of the variables studied.

Despite efforts to standardise patient care, the potential for bias in the discretionary end-point of discharging a patient is an important consideration in this study. Many unstudied variables such as the experience of the person making the final decision, organisation of care, availability of other services and transport, may affect the threshold for discharge or interventions that impact upon discharge. Bias can therefore not be excluded as an explanation for any of the observed differences in this respect, although early discharge planning and the use of agreed criteria for discharging a patient should, however, have minimised this source of potential bias.

Whilst PLOS is a robust outcome in general, there is also a confounding issue surrounding the measurement of this outcome in the hospital of surgery. Whereas most patients are discharged home when they are fit for discharge, some are transferred to other hospitals to continue their recovery. Meanwhile some patients are transferred to their referring hospital for social reasons when they are actually fit for discharge. This makes the interpretation of actual PLOS difficult because postoperative stay at the hospital to which such patients were transferred, and the reason for transfer, was not recorded. Consequently, the data may have been distorted by taking account of the day the patient left the hospital of surgery, as opposed to the day a patient was actually fit for discharge from hospital. Outcomes beyond the initial hospitalisation such as readmission were also not evaluated, as this data is not routinely collected and was therefore not available.

The collection of data regarding the day the patient was fit for discharge, as measured by the agreed criteria for discharge, as well as the day they were actually discharged or transferred, including details regarding the reason for transfer, will enable the extent of these potential sources of bias to be investigated in future studies.

7.2.5.4 Failure to collect data on an important variable

The theory-driven and empirically based approach to the selection of variables minimised the possibility of inadvertently failing to collect data on an important variable.

The comprehensive review of previous multivariate studies identified traditionally studied variables whilst previously neglected psychosocial variables were identified psychosocial literature. In addition two previously unstudied variables were identified as a result of the application of the theoretical framework.

The theoretical underpinnings and the investigation of traditional variables alongside under-studied and new variables strengthen the internal validity of the current study.

7.2.6 EXTERNAL VALIDITY

External validity refers to the extent to which the findings of a study can be generalised to other groups of patients. Assessment of external validity is based on the characteristics of the patients, and the setting and conduct of the study.

7.2.6.1 Characteristics of the patients

The individual characteristics of study sample were compared with the wider CABG population of patients who underwent CABG in NHS hospitals in Great Britain and Ireland, as described in the NACS database report 2003 (Keogh and Kinsman, 2004). The data suggests the study sample was demographically similar to the larger CABG population which affords the study findings with high external validity in this respect.

Consistent with the wider population, women comprised approximately 20% of the study sample whilst just over 70% of patients underwent elective CABG. The proportion of patients receiving one, two, three, four and five bypass grafts was also consistent with that reported in the NACS database for the wider CABG population with most patients (48.6%) having three vessels bypassed.

Increasing age and risk

The characteristics of the study sample reflected the steady increase in the age and risk of the patients selected for CABG that has been observed in the wider population of Great Britain and Ireland (Keogh and Kinsman, 2004).

At 66.7 years, the mean age of the sample was consistent with the predicted rate of increase of two years over five years (Keogh and Kinsman, 2004). The growing proportion of patients over the age of 70 years and relatively few younger patients was also reflected in the study sample (Keogh and Kinsman, 2004).

The general trend observed in the reduction of low risk patients and the increase in higher risk patients was also evident (Keogh and Kinsman, 2004). The study sample comprised a greater proportion of patients in the higher risk groups as measured by EuroSCORE (69% vs 40%), and a corresponding smaller proportion of patients in the lower risk groups.

Co-morbidity

The distribution of co-morbidities in the study sample was also generally comparable to the wider CABG population and reflective of current trends.

The distribution of poor ejection fraction, previous myocardial infarction and peripheral vascular disease has remained relatively stable in the wider population as reported by Keogh and Kinsman (2004). Consistent with this trend, the study sample comprised of a comparable distribution of patients in with a poor, fair and good ejection fraction to that reported for the wider population by Keogh and Kinsman (2004) at approximately 8%, 32% and 60% respectively.

The proportion of patients in the study sample who had had a myocardial infarction was also consistent with that reported for the wider CABG population, with approximately half of patients presenting for surgery having had a previous myocardial infarction. The proportion of patients in the sample with peripheral vascular disease was also comparable at 14.9%.

However, the proportion of diabetic patients and patients with renal dysfunction was higher in the study sample than that reported by Keogh and Kinsman (2004). This may be reflective of the increasing incidence of diabetes and renal dysfunction in both the population of patients presenting for CABG and the general population (Keogh and Kinsman, 2004; Roberts, 2007; Royal College of Physicians of Edinburgh, 2007).

The proportion of patients with hypertension and left main stem disease was higher in the study sample but again this was consistent with the growing proportion of hypertensive patients and patients with left main stem disease presenting for CABG (Keogh and Kinsman, 2004). The distribution of angina was generally less severe than that reported for the wider CABG population but consistent with the decreasing proportion of patients presenting with severe angina at the time of surgery in the wider CABG population (Keogh and Kinsman, 2004).

This comparison of the study sample with the national database demonstrates that the modelling process was derived from a local database that was made up of a representative sample of the wider CABG population. Consequently, the findings of the study may have favourable external validity in relation to the wider CABG population of Great Britain and could therefore be generalised to other centres with a similar case mix.

Centres in countries outside Great Britain and Ireland may also compare the characteristics of their population with the study sample, although due consideration should be given to the significance of the cut-off point and other potential influences on PLOS, such as operative mortality and differences in funding or mode of reimbursement, when assessing the extent to which the findings may be applicable to their centre.

7.2.6.2 Setting of the study

The current study is an example of local risk modelling that reflects the experiences of a single NHS Trust. Whilst it is acknowledged that local influences may not pertain elsewhere, the extent to which the findings may apply elsewhere depends upon the degree to which the study centre and the local population were similar to other centres and populations.

Study centre

The study setting was typical of other cardiothoracic centres in the National Health Service in terms of funding, referral sources and operative mortality. These similarities afford the current study with favourable external validity in this respect.

The extent to which the findings can be applied by centres which vary from the study centre in other ways may be limited. The study centre is a leading specialist centre with one of the largest cardiac departments in the UK and teaching hospital status. The number of operations performed at different centres is known to vary widely as is the proportion of cases that are first-time isolated CABG operations (Keogh and Kinsman, 2004).

CABG operations are performed on two sites, with referrals received from consultant cardiologists for patients in London, Essex and around the UK. This broad referral base may explain why the characteristics of the study samples were generally comparable to the wider CABG population.

In this respect, the extent to which the findings of the current study apply to other centres in the UK may have actually increased since the study was conducted. This is because patients may now choose which hospital they wish to have their surgery rather than this being determined by their geographical location. The characteristics of the local CABG populations may as a consequence become reflective of the wider CABG population in the future as more patients opt to have their surgery at hospitals outside their former geographical referral area.

Local population

The population from which referrals were received was diverse in terms of ethnicity and social deprivation which increases the extent to which the findings may apply to other populations.

Based on 2001 Census data, there are 4.6 million (7.9%) people from non-white backgrounds in the UK with the proportion of people from non-white ethnic groups concentrated in large urban areas. In London non-white ethnic groups comprise 29% of the population whilst in the south east they comprise less than 10% of the population (Office for National Statistics, 2004). Consequently, the referral population was representative of areas with both high and low concentrations of non-white ethnic groups. With 18.3% of the study sample from a non-white ethnic group, this was proportionate to the statistics for the areas from which referrals were received.

Similarly, the referral population consisted of areas with both high and low levels of deprivation. Local authorities in North East London had some of the highest ranking average index of multiple deprivation scores, whilst Essex and the City of London had some of the lowest (Office of the Deputy Prime Minister, 2004).

7.2.6.3 Conduct of the study

The methods used in the study provide the findings with favourable external validity. The combination of a non-experimental observational design, the selection of a total population sample of consecutive patients, and the collection of secondary data, afforded the advantage of enabling a large number of variables to be observed in their natural setting for a relatively large number of patients.

The conduct of the study could not have influenced the extensive amount of data gathered since this was routinely collected for all patients by people other than the researcher and independent of any hypotheses. Due to the retrospective nature of data collection, neither patients nor staff were aware of the conduct of the study, thus diminishing the opportunity for bias in this respect.

Consequently, the observational approach effectively maintained the integrity of the context in which care was provided, including the beliefs, wishes and attitudes of both patients and clinicians as advocated by Black (1996). This is in contrast to the low external validity of experimental studies, such as randomised controlled trials, where the results are highly dependent on the characteristics of the provider, setting and patients, and where healthcare professionals, patients and treatments may be atypical and those who participate may not be representative of the population studied (Black, 1996).

The study achieved high external validity in terms of the representativeness of characteristics of the sample and the setting with the wider CABG population. These aspects were preserved in the conduct of the study by the application of observational methods which did not influence or manipulate these characteristics or the setting in any way. The study findings therefore have high external validity, broadening the extent to which these can be applied to the general CABG population.

7.3 APPLICATION

The main aim of the study was to develop models that could be applied to clinical practice as a tool to improve the speed and quality of the discharge process for patients and the multidisciplinary team. The findings however, have a much broader application than originally intended with implications for policy, nursing and the equity of care provision, as well as clinical practice.

7.3.1 Practice

As originally intended, the findings of the study can be used in practice to improve the discharge process for all concerned. For patients, the prediction of PLOS or discharge within five days can reduce the stress associated with discharge and lead to more patient and carer involvement. The results can also promote proactive discharge planning and potentially reduce PLOS in groups associated with longer PLOS. Meanwhile, the greater consensus consistency between clinicians in care delivery should lead better co-ordination of care.

7.3.1.1 Reducing stress: increasing patient involvement and decisional control

According to the theory of stress, appraisal and coping; stressful situations are less distressing if they can be predicted and the individual can exert some control over them (Lazarus and Folkman, 1984).

Information about the predicted date of discharge allows patients begin the appraisal process and develop coping strategies that are relevant to their own personality and circumstances. Theoretically, maximising the time available for the patient to plan for discharge may reduce the level of appraised stress and assist in the selection appropriate problem-focused coping strategies.

Predicting PLOS, or the likelihood of discharge within a defined timeframe, may also facilitate greater patient involvement and decisional control as it increases the time available for the patient to prepare and make their own arrangements for discharge before admission. This may subsequently reduce feelings of powerlessness and optimise psychological preparation for surgery and discharge home.

The preoperative prediction of PLOS may thus be used as a tool to reduce the stress associated with CABG and promote patient motivation to actively participate in and feel responsible for their recovery. The earlier such predictions can be made, then the earlier the patient can begin to prepare for their admission, discharge and subsequent aftercare.

Discharge planning should ideally commence in preadmission clinic (or before if possible) or, at the latest, on admission to the ward, beginning with a discussion with the patient and family regarding the predicted length of stay/discharge date and other postoperative expectations. It is possible that discharge planning could even be commenced at the referral stage by the referring hospital and become part of the criteria for acceptance.

The discussion should include an assessment of the home situation and available support on discharge or alternative transfer to the referring hospital or convalescent home. The assessment should help the patient plan for discharge and understand what to expect and prepare for on return to their home. It is also an ideal time to identify and plan for any additional nursing and social care needs on discharge and make arrangements in advance to ensure that discharge is not unnecessarily delayed.

It is important that patients and their families feel comfortable and prepared for discharge on the predicted day of discharge and all staff should voice the prediction as a normal length of stay from admission to discharge. However, recovery from CABG surgery is a dynamic process that is subject to unexpected complications and chance effects. For these reasons, it is important that the predicted date of discharge is reviewed daily during the postoperative period by the clinical team. The likely impact of any unforeseen circumstances on the predicted day of discharge should be discussed with the patient at an early stage and the prediction modified to ensure that any possible failure to meet the original target does not become a source of stress.

Predicting the date of discharge in this way may, theoretically, reduce the stress of undergoing CABG and prepare the patient for coping before and within hospital and also on discharge, by reducing feelings of helplessness, and increasing the predictability and controllability of the event. However, further research is needed to investigate the relationship between powerlessness and empowerment with PLOS after CABG and whether facilitating feelings of control can actually impact upon PLOS. It logically follows that if the amount of control a person feels he or she has can influence their participation in decision-making and care; then this may also influence their PLOS. However, the suggested relationship between the patient's feelings of powerlessness experienced during CABG and their recovery rate is not supported in existing literature (Sarpy et al, 2000).

7.3.1.2 Proactive discharge planning

The predicted PLOS or probability of discharge within five days can inform proactive discharge planning and allow greater attention to be focussed on the variables identified within the models to influence these outcomes. This may subsequently reduce PLOS for patients expected to require longer in-hospital recovery times.

New knowledge with a current application has been made available as a result of the current study. Based on the findings of the univariate analysis, knowledge of the patient characteristics associated with longer PLOS can now be used to proactively manage care and prioritise early interventions by the multidisciplinary team. Careful assessment should currently be made of the variables found to be associated with longer PLOS or discharge after five days of surgery including older age, female gender, being widowed, living alone and co-morbidity, in order to ensure discharge planning is reflective of the individual needs of these patients.

This subsequently also allows greater attention to be focused on reducing the impact of these variables on PLOS which may reduce PLOS for this group of patients. Prolonged PLOS is not desirable in terms of quality as well as business objectives. Reducing PLOS in this way would reduce exposure to, and therefore potentially lead to a reduction in, healthcare associated infections (National Audit Office, 2000).

Whilst multivariate models are currently unable to predict the specific outcome for every patient, the results can inform patients and hospital staff of the likely PLOS for a group of patients with a similar risk profile undergoing first time CABG and those likely to require a PLOS longer than five days. This information is important for bed management and planning resources.

The following variables were all identified as important predictors of PLOS by multivariate analysis; age, marital status, index of deprivation, ejection fraction, renal disease, peripheral vascular disease, diabetes and Parsonnet score. As such, they should all be taken into account when planning discharge and estimating PLOS for groups of patients, with greater consideration given to the patient's demographic and psychosocial circumstances, pre-existing morbidity, and the severity of their illness. In particular, being over 70 years old, widowed, living in an area of relatively high deprivation, having a poor ejection fraction, renal disease, peripheral vascular disease and insulin-dependent diabetes, and a relatively high Parsonnet score should all alert the clinician to the likelihood of a longer PLOS and a decreased likelihood of discharge within five days of CABG than otherwise.

Identifying the volume of these patient groups can inform the planning of hospital resources such as theatre time and staffing, and beds, ensuring optimal usage and minimal waste. Similarly, hospitals can use the models to estimate the cost of providing CABG for their referral population, and to calculate the volume of operations they can provide within a defined time period based on predicted PLOS.

7.3.1.3 Co-ordination of care

The application of prediction models can help improve the discharge process for the patient by facilitating better co-ordination of care leading towards the predicted day of discharge. This could increase the efficiency of the discharge process, help reduce unnecessary delays, and improve communication between all concerned.

If predicted dates of discharge are incorporated into the patient's discharge plan in preadmission clinic or on admission to hospital so that everyone is aware of the expected discharge date, care can then be coordinated towards this date by the multidisciplinary team. The greater consensus and consistency in care delivery that may be achieved by the multidisciplinary team as a result of effectively communicated predicted dates of discharge should improve the speed and efficiency of the discharge process. Investigations can be requested and referrals made early enough so that decisions to discharge are not delayed if the patient meets the criteria for safe discharge on the expected day of discharge. This would reduce the number of avoidably delayed discharges which not only adversely affect the availability of beds but are frustrating for patients who are ready to go home.

There is also a utilitarian ethical duty to reduce the amount of avoidably delayed discharges since this will increase the number patients that can be treated with same resources. A saving in bed days will also improve waiting times and reduce cancellations which would benefit future patients on the waiting list as well as maximising the use of constrained resources in the current economical climate

Some patients will inevitably suffer unpredictable postoperative complications or unforeseen social problems that will delay their discharge. Whilst not all patients will therefore be discharged on their predicted date, the application will ensure that the focus remains on discharge planning throughout the patient's stay. This will likely result in a shorter length of stay than otherwise as well as reduce avoidable delays.

As a tool to improve the co-ordination of care, the benefits of improving practice in this way extend to patients, clinicians and healthcare organisations. Although the date is not fixed, predicted dates of discharge or expected length of stay should facilitate better communication between clinicians, patients and their families, caregivers and between the hospital and community settings.

Patients, their families and caregivers would clearly benefit from improvements to the co-ordination of care provided to them. The greater efficiency of care and improved communication, together with greater patient involvement and decisional control, should positively impact upon quality indicators that include national patient surveys now coordinated by the Care Quality Commission (Care Quality Commission, 2009). As patient satisfaction with the care they experience increases, the number of complaints by patients regarding their discharge should also decrease.

Patient and carer experience, delayed discharges, length of stay, healthcare associated infections, waiting times and cancellations are all clinical performance indicators that are measured as part of the NHS performance assessment framework that was originally set out in A First Class Service (Department of Health, 1998). By positively impacting upon these measures, the application of prediction models to clinical practice may also contribute to an improvement in the hospital's national performance rating.

7.3.2 Policy

The development and validation of models to predict PLOS for individual patients is consistent with policy guidance and current thinking about improving the hospital discharge process. Predicted or estimated dates of when a patient is “fit for discharge” are central to current policy guidance and are important for nurses and the multidisciplinary team to advise patients about when they are likely to be ready to go home (Department of Health, 2004a).

This study supports the development of this policy by highlighting the potential wide-ranging benefits for patients, clinicians and hospitals if accurate predictions of PLOS can be made in the preoperative period. By identifying the gaps that remain in the current knowledge of predicting PLOS after CABG and key areas for the direction of future research, this study is also instrumental in the development of such a policy for CABG patients. The learning that occurred as a result of this study may also apply to other surgical procedures, potentially increasing the scope of the development.

Whilst the prediction of PLOS requires further development, the findings of the univariate analysis can be used to inform future policy decisions regarding CABG surgery. These findings have high external validity and thus provide a contemporary analysis of current trends in the characteristics of the CABG population and the influence of these characteristics on PLOS. Applied to trends of these characteristics in the general population, this knowledge can be used at the population level to estimate PLOS and costs of future CABG populations and the volume of operations that can be provided by existing facilities and resources. This information may subsequently influence policy decisions on funding and CABG provision.

The principles and methods used in this study can be applied to any surgical procedure with a predictable recovery period. This study may therefore be used in the same way to inform policy decisions regarding the funding and provision of a much wider range surgical procedures.

7.3.3 Equity

The identification of certain groups of patients who are consistently likely to require longer lengths of in-patient stay after CABG could have implications for the ethical principle of equity. The findings of the study may subsequently inform decisions regarding the development of strategies to increase the equity of health and the equitable distribution of healthcare resources.

7.3.3.1 Equity of health

Equity has been defined as: "the absence of potentially remediable, systematic differences in one or more aspects of health across socially, economically, demographically, or geographically defined population groups or subgroups" **(**International Society for Equity in Health, 2001).

The findings of this study add to the increasing body of evidence that older, female patients, and those living in areas of relatively higher deprivation experience worse outcomes after CABG. It has been proposed that criteria for assessing whether such health inequalities are unfair should include whether they are due to inherent biological variation, due to informed individual choices, or are potentially avoidable (Whitehead, 1992).

A number of possible explanations for the longer PLOS experienced by these groups in the current study have been discussed and include physiological and psychosocial mechanisms but the extent to which the differences were avoidable is not available from the data.

It is arguable that by identifying patients at risk of longer PLOS using prediction models this will allow the multidisciplinary team to better anticipate and proactively manage the needs of these patients. This may therefore be an effective strategy to narrow the difference in PLOS between these groups if they are avoidable.

As the logistic regression models were much better at predicting PLOS greater than five days, it is suggested that the application of these models may be the most appropriate way to identify those patients for whom greater attention should be focused. The identification of those patients likely to require a postoperative stay longer than five days will allow this attention to be focused on both the prevention of potential complications and the early detection and prompt treatment of actual complications that delay discharge in this group of patients. As well as leading to a potential reduction in the PLOS for patients in this group, it may also improve other clinical outcomes, such as postoperative morbidity and hospital acquired infections.

7.3.3.2 Equitable distribution of healthcare resources

To achieve an equitable distribution of healthcare resources this must be considered ethically just and reasonable in the circumstances. If older, female, widowed and renal patients as well as those who live alone require longer PLOS than patients without these characteristics then it logically follows that these patients have a greater need for more resources.

Arguably, more resources should therefore be allocated to service providers with greater proportions of these characteristics in their referral population in order for the delivery of care to be equitable. Hospitals may therefore wish to account for the proportion of these characteristics in their referral population when estimating the costs of providing CABG.

7.3.4 Nursing

The findings of this study can also be of benefit to healthcare professionals leading the discharge process. This is particularly so for nurses as the scope of nursing practice expands in line with the ten key roles shaping the future of nursing, set out by the Chief Nurse for England in The NHS Plan (Department of Health, 2000a), Making a Difference (Department of Health, 1999). Professional development in the form of increased responsibility for the discharge process has also been highlighted more recently in the high impact actions for nursing and midwifery (NHS Institute for Innovation and Improvement, 2009).

The decision that a patient is medically fit for discharge can only be made by the patient’s consultant or by someone to whom the consultant has delegated authority. Nurse-led discharge has been defined as “the whole process of discharge by nurses, following decisions made by nurses, using criteria, protocols or given set of principles" (Lees, 2004: 31).

The findings of this study can be used to inform the development of nurse-led discharge protocols for CABG surgery. In the future this would include predicting PLOS or the likelihood of discharge within five days at first contact with the patient and managing care towards this date. Although the predictive models currently require further development, the identification of the characteristics that are associated with longer PLOS can currently be used to guide the assessment process, alerting the nurse to the need for greater attention to be focused on proactive discharge planning for patients presenting with these characteristics.

The Department of Health (2004a) has proposed that at least 80% of hospital patients can be classified as "simple discharges", referring to patients who are discharged into their own home and have simple ongoing healthcare needs which can be met without complex discharge planning. These are people being discharged home with minimal care needs and the toolkit set out by the Department supports the idea of these patients being discharged by nurses (Department of Health, 2004a). A potential example of a "simple discharge" would be those patients identified at an early stage as being likely to achieve discharge within five days of CABG, subject to no post-operative complications arising.

It is envisioned that nurse-led discharge could improve the patient experience and patient satisfaction by facilitating a timelier and better co-ordinated discharge and have a positive impact on bed management and the achievement of performance targets (Department of Health, 1999; Department of Health, 2000a). One advantage of a nurse-led discharge is the fact that nurses are present 24 hours a day, seven days a week. This means the decision to discharge a patient can be made out of hours and at weekends and is not delayed until the ward round or a doctor is available thereby reducing fluctuations in the number of discharges and the subsequent availability of beds (Department of Health, 2004a). The implementation of nurse-led discharge is already occurring in some areas although Lees (2004) has commented that nurse-led discharge is commonly interpreted as the transference of responsibility for the discharge decision from doctors to nurses.

The findings of the study have both a current and anticipated implications for clinical practice, policy, equity, and nursing. Contemporary knowledge of the variables that are associated with PLOS and discharge within five days may currently be applied to local practice by the multidisciplinary team to inform the discharge process. Meanwhile, the application of models to predict PLOS, or discharge within a set timeframe, for individual patients requires further investigation but has a number of inter-related potential benefits. These include; increased patient involvement and satisfaction, better communication and consistency of care, as well as reducing length of stay and avoiding delayed discharges. As a result of this costs will be reduced and bed and waiting list management within the hospital improved.

The potential benefits are far reaching and extend to patients, their families, carers, as well as clinicians working in both the hospital and the community, managers of the service, and organisations as a whole.

Further research is now required in order to develop and validate local models to predict PLOS and/or discharge within five days of surgery that can be used in practice. Further research will also be required after implementation of any such models or univariate findings to determine if their application to practice will actually result in the anticipated benefits for patients, their families, carers, clinicians and healthcare providers, and also to investigate the impact on other patient outcomes such as readmission rates and patient-reported outcome measures.

7.4 RECOMMENDATIONS FOR FURTHER RESEARCH

The results of the current study indicate that further research is required to develop models that can usefully be applied in practice to predict PLOS for individual patients. The findings and learning that occurred as a result of this study highlight what still needs to be known about the complexity of predicting PLOS after CABG and can inform the direction of future research as well as the selection of methods to develop such models.

7.4.1 Direction of future research

7.4.1.1 Theory-driven research

As in the current study, future research should also incorporate a theoretical framework. This is important for the generation of new knowledge from research by facilitating the identification of relevant areas for study and the analysis and interpretation of the findings.

Stress, appraisal and coping are central to the theoretical framework applied in this study but further empirical work is required in order to better understand how these processes relate to patients undergoing CABG. This includes investigating the association between perceived stress and other measures of stress such as cortisol levels, and the coping methods used by different groups of patients and their subsequent influence on PLOS. Similarly, additional research is also required to investigate whether predicting PLOS can actually reduce the perceived stress associated with impending CABG as theorised.

The assumed benefits of predicting PLOS in the preoperative period also need to be evaluated in order to provide justification for proceeding with this approach and allocating resources towards this aim. This includes both quality and business objectives such as patient-reported measures of satisfaction and involvement in decision making and other aspects of postoperative recovery such as decreasing PLOS and readmission rates.

7.4.1.2 Psychosocial variables

The current, theory-driven, study has begun the investigation of variables that were not previously included in multivariate analyses of PLOS. These psychosocial variables were among those identified as important predictors of PLOS which indicates they should now be included in all future attempts to model PLOS in order to reflect individual differences in both the physical impact of CABG and behavioural aspects of recovery.

This study adds to the developing field of research investigating the role of psychological and social variables in explaining various outcomes following cardiac surgery. However, the potential impact of a wide range of other psychosocial variables that were not investigated in this study has not yet been explored. In accordance with the theoretical framework of this study, the time from confirmation of the need for CABG until actual surgery has been identified as a source of stress for both patients and their families which may be manifested in negative emotional responses such as anxiety, depression, fear and anger (Bressler et al, 1993; Bengston et al; 1996; Mark et al, 1997; Fitsimons et al, 2000). While these theoretical constructs have frequently been studied in preoperative cardiac surgery patients, relatively little is known of the influence of these variables on PLOS. The inclusion of these and other preoperative psychosocial variables identified within the theoretical framework such as perceived social support, in addition to the variables investigated in the current study, may therefore yield more information about this complex relationship.

7.4.1.3 Broadening the scope of the research

There are several potential areas in which the focus of the research in this study can be broadened. Ideas for future research include repeating the study using a larger multi-centre sample in order to investigate between hospital characteristics that were not investigated in this study. Other types of cardiac surgery such as valve replacements could also be included so that the findings can then be generalised to the wider cardiac surgery population. Resultant models could then be applied to a greater number of individuals and the scope for planning resources by cardiothoracic units increased.

Future studies could also investigate and develop models for different surgical techniques such as separate models for CABG, aortic valve replacement and combined procedures. Different models could also be developed for patients undergoing elective and non-elective surgery. However, the complexity and practicality of increasing the number of models in practice would need to be evaluated in order to establish the benefits of this approach and select the most beneficial model.

Future studies could also investigate the development of models that modify the preoperative prediction of PLOS as the patient progresses through their stay. As operative and postoperative variables that are not known in the preoperative period become known, such as bypass time, anaesthesia time, anaesthetic agents and postoperative complications these can be added to the model and the preoperative predicted PLOS modified. This may become a much more viable option in the future as routine audit data on these variables becomes more readily available.

Whatever the way in which this research topic develops in the future, the models will be constantly evolving. As knowledge and practice in CABG surgery develops it is possible that discharge within four or even three postoperative days may become the norm. Alternatively, as the age and risk of patients presenting for surgery increase, current practice may shift towards discharge within six or seven postoperative days. Consequently, any model will require periodic recalibration.

7.4.2 Methodological recommendations

The recommendations for the methods used in future research studies logically follow the limitations identified in the discussion of the current study. These include the prospective collection of complete data based on the most up-to-date measurement tools and the assessment of the psychological variables at multiple time points.

7.4.2.1 Collection of complete data

Further research should repeat the study on the local population, ensuring that data collection for the sample of patients identified is as complete as possible. This will increase the number of complete cases available for analysis and minimise the possibility of developing models derived from a small subset of the sample which differentially excludes some groups of patients.

The implementation of measures such as the use of mandatory fields in the SCTS database for the prospective collection and validation of the variables of interest should greatly improve the completeness of data. It is also recommended that data collected for contribution to the SCTS database and should be extended to include the variables for which the data was retrieved from the patient’s electronic record in the current study. The SCTS database was a much more complete and reliable source of data so including variables that were frequently missing from the electronic patient record such as living alone and employment should increase the capture of this information.

As the SCTS database develops and audit interest in outcome measures other than mortality grows, such as PLOS and patient-reported outcome measures; then a wider range of variables are likely to be scrutinised. It is therefore possible that psychosocial variables will be collected in the future, particularly if there is evidence that these variables influence patient outcomes. The secondary analysis of the SCTS audit data is therefore recommended in future studies.

7.4.2.2 Additional variables

The number of variables for which data is collected should be increased to include the day on which they were actually fit for discharge, as well as the day they left hospital where this is delayed for non-clinical reasons. This will enable the prediction of this outcome to be investigated and account for discharges that are delayed unnecessarily.

Meanwhile collecting data on the patient’s destination on discharge and their reason for transfer to another hospital may also add to the understanding of delayed discharges and the actual in-hospital PLOS of patients who continue their physical recovery at another hospital.

7.4.2.3 Measuring psychological variables

Data on the psychological variables should be collected for all eligible patients in the study in order ensure the sample is representative of the population and the resultant size is sufficient for the multivariate analyses. This data should also be collected at several time points during the preoperative period, using additional instruments, to fully investigate these variables which may vary over time and with the context in which the data is collected.

For elective patients this would necessitate obtaining informed consent to participate and administering the questionnaires at the patient's first outpatient appointment, and then again at preadmission clinic and on admission as a minimum. For non-elective patients, psychological assessment should commence at the first appropriate time in the preoperative period if this is possible. The logistical implications of these recommendations mean that the research should ideally be conducted by a fully funded research team.

7.4.2.4 Newer statistical modelling techniques

Future research using newer statistical modelling techniques, such as "data mining", are also recommended for investigation, particularly if these can be applied to large datasets which include the variables recommended for further study.

Data mining techniques are designed to explore data for patterns or relationships between the variables. They allow patterns and trends in the data to emerge without hypothesising a priori or limiting the number of variables, and are less affected by low frequency of a particular variable than multivariate regression techniques. Such techniques applied to large datasets of a large number of variables may provide suitable initial means of exploring and identifying new and unexplored variables, including under-researched psychosocial variables, for further hypothesised research using traditional statistical modelling techniques, and the performance of these models then evaluated.

This is an increasingly viable and attractive direction for future research due to the current expansion of electronic medical records in the NHS. This affords greater access to large amounts of observational data and many possibilities for real-time analysis and tracking patients to measure other outcomes which may be associated with PLOS or certain patient groups such as those readmitted to other hospitals. Meanwhile, the increased computational power means that the assumptions and limitations of traditional statistical modelling techniques can be avoided by using advanced algorithmic techniques.

7.4 SUMMARY

The results of the study provide a contemporary analysis of the influence of preoperative variables on PLOS and discharge within five days of CABG in the local population. Patients who are older, female, widowed, live alone or present with co-morbidities such as renal impairment are more likely to experience longer PLOS. These findings can currently be used in practice to assist patients in making informed decisions regarding their discharge planning and used by hospital staff to inform the discharge process as well as assisting with resource planning.

The prediction models derived from these variables did not perform well and subsequently require further development before these can usefully be applied in practice. The models were, however, much better at identifying patients discharged after five days which, with further development and validation, may also have implications for practice.

This investigation has demonstrated that predicting PLOS and discharge within, or after, five days of CABG is an important area of research and that improving practice in this way can benefit patients and their families, clinicians, hospital managers and organisations. The ability to accurately predict these outcomes could result in more patient involvement and decisional control, more proactive discharge planning, and better co-ordination of care. Meanwhile, the greater consensus within the multidisciplinary team may achieve more consistency and efficiency, avoid delayed discharges and improve communication and patient satisfaction. Focusing attention on those likely to require longer PLOS may also reduce PLOS for this group of patients and therefore reduce their exposure to hospital acquired conditions.

The findings of the study have high external validity due to the selection of a non-experimental observational design, the characteristics of the sample and the setting of the study. The findings may therefore be applied to the wider CABG population with implications for clinical practice, policy, nursing, and equity.

A number of recommendations have been made as a result of this study in order to assist in the generation of further knowledge in this area of research. These include the recommendations that future research should also be underpinned by theory as well as extending and expanding the investigation of psychosocial variables.

Recommendations for future methods include addressing the limitations identified as part of the current investigation and exploring the possibilities for future analyses as advances in computer technology are applied to patient records within the NHS.

CHAPTER 8

CONCLUSION

“Can postoperative length of stay or discharge within five days of CABG be predicted from preoperative patient variables?” is a topical research question; it is consistent with current policy guidelines, important for improving the individual patient pathway, and also useful for the planning of services and resources.

The outgoing Government’s vision was of a 21st century health service, designed to meet the needs of the patients. One of the ways in which this Government wanted to achieve its vision was by implementing protocol-based care, or clinical guidelines based on the best available evidence to support clinicians during the decision-making process.

Estimating a date for discharge is a key concept in current policy guidance. With a clear emphasis on early discharge planning, an indication of length of stay for common conditions and procedures has been viewed as a key starting point.

Managing patient care to a predicted date of discharge has provided the impetus for the current study. The ability to predict PLOS or discharge within five days of CABG can improve the patient pathway by facilitating patient involvement in the discharge planning process and improve the coordination of care by the clinical team. It can also provide useful information when making decisions about the development of services, as well as cost and resource utilisation.

It is evident that advances in cardiac surgery have lead to better surgical outcomes and reduced PLOS despite increasing numbers of older and higher risk patients undergoing CABG in recent years. The worsening risk profile of patients referred for CABG together with the economic pressure to contain costs, has necessitated a better and more contemporary understanding of the variables that influence of PLOS in this patient group. The results of the study's univariate analysis demonstrated that the characteristics of the study sample mirrored the changing characteristics of the wider CABG population.

The current study has also provided a contemporary univariate analysis of traditionally studied preoperative variables that influence PLOS as well as the magnitude of their influence. As such, it provides valuable information regarding current trends in the direction of influence of each individual variable. When combined with knowledge of national trends in the prevalence of these variables in the CABG population, as well as the general population, this also provides further information on the likely importance of these variables in the future.

The review of the literature showed that considerable effort had already been made to study and understand the factors that influence and improve our ability to predict expected PLOS from multiple variables. It is clear from the findings of previous studies that recovery from CABG is a complex process that is associated with preoperative demographic and clinical variables, but that these variables do not adequately predict PLOS by multivariate analysis.

The review of the literature also noted that gaps remained in the body of knowledge at that time because most research had centred on demographic, physiological and procedural variables, and neglected other potentially influential psychosocial variables.

Postoperative and organisational variables, as well as chance occurrences, also exert an influence on PLOS but the current study has focussed solely upon variables known in the preoperative period for the purpose of preoperative planning. By concentrating on these variables, the study potentially would produce results which would be of more value to the clinical team with the ability to predict PLOS being perhaps of greatest use at or before the time of the patient being admitted.

To the author's knowledge, this study is the first to have incorporated a theoretical framework to guide and inform the research process in this area of investigation. The application of the Theory of Appraisal and Coping (Lazarus and Folkman, 1984) provided a frame of reference for the research question and identified two potentially important psychological variables for investigation. The conceptualisation of stress and coping has also provided a useful perspective within which to view the application of the findings as part of interventions directed towards reducing levels of stress and improving coping within the patients undergoing CABG.

The results of the multivariate analysis add to previous knowledge and shows that CABG remains a complex area for the prediction of either PLOS or discharge within five days of surgery. The inclusion of previously neglected variables in the modelling process however, failed to increase the precision achieved in previous models or offer added explanatory power. The variables included in the study models and the resultant predictive regression equations were relatively poor predictors of PLOS and discharge within five days of surgery in both the sample from which they were derived and the validation sample.

An unforeseen result however, was that the models were able to predict in almost 80% of cases those patients who would not be discharged within five days. This in itself is of importance to clinicians, in that it potentially would allow a greater concentration of resources upon those identified as unlikely to achieve discharge within five days. This could lead to a reduction in those patient's PLOS with great benefits to the patients and all those involved in their care, as well as resource and budget planning within the hospital.

The methods employed in the study provided practical and economic advantages and were duly selected for both their feasibility to the research situation and their ability to address the research question and the aims of the study. The findings of the current observational study are strengthened by the large sample size and the comprehensive set of variables considered for risk modelling. New knowledge about the possible univariate and multivariate influence of previously neglected psychosocial variables on PLOS and discharge within five days of surgery has also been made available. The findings of the current study better reflect contemporary patterns of care than earlier studies and have high external validity.

The prediction of PLOS remains an important area for further investigation. If such a prediction can made at an early stage; such as in the preadmission clinic or earlier, and it is coupled with greater consistency within the multidisciplinary team to work towards the discharge timeframe identified; PLOS may be decreased, surgical throughput optimised and at the same time the quality of patient care and the overall patient experience improved.

The current study adds to the existing body of knowledge relating to the prediction of PLOS after CABG by investigating both accepted demographic, physiological and procedural variables, as well as psychosocial variables that have been identified within the literature to influence PLOS, or derived from the theoretical framework of the study.

Whilst there are implications for both cost and convenience, the preoperative collection of psychosocial data in addition to traditional clinical data may yet yield information independent of physiological, demographic and procedural variables and help explain the variation left unaccounted for in existing models. This could then further assist in improving the current ability to predict PLOS after CABG surgery, with all the potential benefits.

The need for further research has been identified and recommended before the findings of this study can be used in practice as part of a total approach to improve the discharge process for all concerned. The current expansion of computerised patient records and advances in computer technology also offer exciting possibilities for further exploring the prediction PLOS in future CABG populations.

Appendix 1

The Parsonnet Score

Parsonnet score

A method of Uniform Stratification of Risk for evaluating the results of surgery in acquired adult heart disease
Circulation (1989) 79: Suppl I: 3-12

In the original paper, an additive score of 0-4 translated to an average operative mortality of 1% (low risk); a score of 5-9 an operative mortality of 5% (elevated risk); a score of 10 – 14 a mortality of 9% (significantly elevated risk), a score of 15 – 19 a mortality of 17% (high risk) and a score of over 19 a mortality of 31% (very high risk).

	Factor	Definition	Score
Patient-related factors	Gender	Female	1
	Morbid obesity	Body mass index >35	3
	Diabetes	Any history of diabetes regardless of duration or treatment. Latent diabetes of pregnancy excluded	3
	Hypertension	A history of blood pressure greater than 140/90mmHg on two occasions, or lower if on medication	3
	LV dysfunction	Good (≥50%) Fair (30-49%) Poor (<30%)	0 2 4
	Age	70-74 years old 75-79 years old > 80 years old	7 12 20
	Re-operation	Second operation Third (or more)	5 10
	Intra-aortic balloon pump	Prior to surgery. Do NOT include IABP's inserted prophylactically just prior to surgery because these represent post-operative support.	2
	Left ventricular aneurysm	Aneurysmectomy	5
	Recently failed Intervention	Within 24 hours of operation > 24 hours, op on same admission	10 5
	Renal	Dialysis dependency	10
	Catastrophic states	e.g. acute structural defect, cardiogenic shock, acute renal failure	10-50
	Other rare circumstances	e.g. paraplegia, pacemaker dependency, congenital heart disease in adults, severe asthma	2-10
Surgery-related factors	Mitral valve surgery	Systolic PA pressure <60 mmHg	5
		Systolic PA pressure ≥60 mmHg	8
	Aortic valve surgery	AV pressure gradient ≤120 mmHg	5
		AV pressure gradient >120 mmHg	7
	CABG at the time of valve surgery		2

<u>The Parsonnet score</u>
<u>From: The Society of Cardiothoracic Surgeons of Great Britain and Ireland National Adult Cardiac Surgical Database Report 2000 - 2001 by B Keogh and R Kinsman, Oxfordshire: Dendrite Clinical Systems Ltd, (2002: p241).</u>

Appendix 2

The EuroSCORE

EuroSCORE European System for Cardiac Operative Risk Evaluation Score European system for cardiac operative risk evaluation Eur. J. Cardiothorac. Surg. 1999 16; 1; 9-13			
weights add up to an approximate percentage predicted mortality			
	Factor	**Definition**	**Score**
Patient-related factors	Age	Per 5 years or part thereof over 60	1
	Gender	Female	1
	Chronic Pulmonary disease	Long-term use of bronchodilators or steroids for lung disease	1
	Extra cardiac arteriopathy	Any one or more of the following: claudication, carotid occlusion or >50% stenosis, previous or planned surgery on the abdominal aorta, limb arteries or carotids	2
	Neurological dysfunction	Disease severely affecting ambulation or day-to-day functioning	2
	Previous cardiac surgery	Previous surgery requiring opening of the pericardium	3
	Serum creatinine	>200 µmol l-1 pre-operatively	2
	Active endocarditis	Patient still under antibiotic treatment for endocarditis at the time of surgery	3
	Critical pre-operative state	Ventilation before arrival in the anaesthetic room, pre-operative inotropic support, intra-aortic balloon counterpulsation (IABP) or pre-operative acute renal failure (anuria or oliguria <10ml/hr)	3
Cardiac related factors	Unstable angina	Angina requiring iv nitrates until arrival in the operating room	2
	LV dysfunction	Moderate (EF 30 - 50%) Poor <30%	1 3
	Recent myocardial infarct	<90 days	2
	Pulmonary hypertension	Systolic PA pressure >60 mmHg	2
Operation related factors	Emergency	Carried out on referral before the beginning of the next working day	2
	Other than isolated CABG	Major cardiac operation other than or in addition to CABG	2
	Surgery on thoracic aorta	Ascending, arch or descending aorta	3
	Post infarct septal rupture		4

The EuroSCORE
From: The Society of Cardiothoracic Surgeons of Great Britain and Ireland National Adult Cardiac Surgical Database Report 2000 - 2001 by B Keogh and R Kinsman, Oxfordshire: Dendrite Clinical Systems Ltd, (2002: p242).

APPENDIX 3

Patient Documentation

Contents

- Patient Information Sheet
- Written Consent Form
- The Perceived Stress Scale
- The Multidimensional Health Locus of Control Scale

• PATIENT INFORMATION SHEET

Study title: Can discharge within 5 days of first time isolated coronary artery bypass graft (CABG) surgery be predicted from preoperative patient variables?

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

1. What is the purpose of the study?

Most patients are discharged from hospital after 5-8 days after CABG surgery. The purpose of this study is to investigate whether an individual patient's day of discharge can be predicted using information we already know about the patient's medical and social history, together with additional information from two questionnaires.

If the day of discharge can be predicted preoperatively, this will allow us to clarify the individual patient's expectation of his/her recovery and improve the discharge planning process with all involved.

In situations where the day of discharge is predicted to be longer than 5 days, this allows the reasons for prolonged lengths of recovery to be identified and facilitates the development of strategies to minimise preventable and treatable postoperative complications that delay discharge.

2. Why have I been invited?

All patients undergoing first time isolated CABG surgery between 1st September 2007 and 31st January 2008 will be invited to take part in the research.

3. Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form to show that you have agreed to take part. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the standard of care you receive.

4. What will happen to me if I take part?

You will be involved in the research for the duration of your hospital stay. At your routine preadmission visit you will be asked to complete two short psychometric questionnaires that will be forwarded to the researcher and not used in any way to influence your treatment plan.

The study does not involve any other intervention. All patients are reviewed prior to discharge from hospital by a cardiothoracic registrar, regardless of whether they are included in the study. If you are not considered fit for discharge 5 days after your operation, you will not be discharged until a registrar deems you to be medically fit and all discharge plans/services are in place.

5. What do I have to do?

Apart from completing the questionnaires prior to surgery, you will not be asked to do anything else.

6. What are the possible disadvantages and risks of taking part?

There are no risks involved and your medical and nursing care will not be influenced by your decision to participate.

7. What are the possible benefits of taking part?

There is no intended clinical benefit to the patient taking part in the study.

> The information we get from this study may help us to improve discharge planning by informing decisions on changes and improvements to care for future patients after CABG surgery.

8. What if new information becomes available?

> Sometimes during the course of a research project, new information becomes available about the topic that is being studied. If this happens, your research contact person will tell you about it and discuss with you whether you want to continue in the study. If you decide to withdraw, your care will continue as before. If you decide to continue in the study you will be asked to sign an updated consent form.

Also, on receiving new information your research contact person might consider it to be in your best interests to withdraw you from the study. He/she will explain the reasons and arrange for your care to continue.

9. What happens if there is a problem?

We would not expect you to suffer any harm or injury because of your participation in this study. If you are harmed by taking part in this study, there is no special compensation arrangement. If you are harmed due to someone's negligence, then you may have grounds for legal action but you may have to pay your legal costs. Regardless of this, if you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, the normal National Health Service complaints mechanisms should be available to you.

Please contact Patient Advisory Liaison Service (PALS) if you have any concerns regarding the care you have received, or as an initial point of contact if you have a complaint. Please telephone *** **** ****, minicom *** **** ****, or email pals@*************.nhs.uk, you can also visit PALS by asking at any hospital reception.

10. Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you which leaves the hospital will have your name and address removed so that you cannot be recognised from it.

11. What will happen to the results of the research study?

The results of the research will be disseminated within the Trust to all cardiothoracic surgeons, cardiac nurses and senior managers. It is also anticipated that the results will be published in a healthcare journal and presented at a health conference. You will not be identified in any report/publication.

12. Who is organising and funding the research?

The study is funded by ************** NHS Trust, Special Trustees of ******************.

13. Who has reviewed the study?

All research in the NHS is looked at by an independent group of people, called a Research Ethics Committee, to protect your safety, rights, wellbeing and dignity. This study has been reviewed and given favourable opinion by the *********** Local Research Ethics Committee.

14. Contact for Further Information

Michelle Burrough
Senior Sister / PhD Student

Address removed to maintain anonymity of Trust

Thank you for taking part in this study

You will be given a copy of the information sheet and a signed consent form to keep

Michelle Burrough
Senior Sister/PhD Student

Address removed

WRITTEN CONSENT FORM:

(11TH JUNE 2007 VERSION 2)

Title of research proposal: Can discharge within 5 days of first time isolated coronary artery bypass graft surgery be predicted from preoperative patient variables?

REC reference number: 04/Q0604/52

Name of Patient (Block Capitals):

Patient No:

Address:

- The study organisers have invited me to take part in this research. ☐
- I understand what is in the patient information sheet about the research. ☐
- I have a copy of the patient information sheet to keep. ☐
- I have had the chance to talk and ask questions about the study. ☐
- I know what my part will be in the study and I know how long it will take. ☐
- I have been told about the questionnaires I will be given. ☐
- I understand that I should not actively take part in more than 1 research study at a time. ☐
- I know that the ******************* Research Ethics Committee has seen and agreed to this study. ☐
- I understand that personal information is strictly confidential: I know the only people who may see information about my part in the study are the research team or an official representative of the organisation which funded the research. ☐
  I understand that my personal information may be stored on a computer. If this is done then it will not affect the confidentiality of this information. All such storage of information must comply with the 1998 Data Protection Act. ☐
- I freely consent to be a subject in the study. No-one has put pressure on me. ☐
- I know that I can stop taking part in the study at any time. ☐
- I know if I do not take part this will not affect my care ☐
- I know that if there are any problems, I can contact: ☐

Ms Michelle Burrough, Senior Sister/PhD Student
Tel. No: *** ***** *****

Patient's Signature: .... Date: ....

The following should be signed by the clinician responsible for obtaining consent.

As the Investigator responsible for this research or a designated deputy, I confirm that I have explained to the patient named above the nature and purpose of the research to be undertaken.

Clinician's Name: ....Clinician's Signature: .... Date:………………….

The Perceived Stress Scale

Name:

Patient Number:

Date:

The questions in this scale ask you about your feelings and thoughts during the last month.

In each case, you will be asked to indicate by circling how often you felt or thought a certain way.

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly? 0 1 2 3 4
2. In the last month, how often have you felt that you were unable to control the important things in your life?.. .0 1 2 3 4
3. In the last month, how often have you felt nervous and "stressed"?......0 1 2 3 4
4. In the last month, how often have you felt confident about your ability to handle your personal problems? 0 1 2 3 4
5. In the last month, how often have you felt that things were going your way?.. 0 1 2 3 4
6. In the last month, how often have you found that you could not cope with all the things that you had to do? 0 1 2 3 4
7. In the last month, how often have you been able to control irritations in your life?... 0 1 2 3 4
8. In the last month, how often have you felt that you were on top of things?.. 0 1 2 3 4
9. In the last month, how often have you been angered because of things that were outside of your control? 0 1 2 3 4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?................. 0 1 2 3 4

The Multidimensional Health Locus of Control Scale

Instructions: Each item below is a belief statement about your medical condition with which you may agree or disagree. Beside each statement is a scale which ranges from strongly disagree (1) to strongly agree (6). For each item we would like you to circle the number that represents the extent to which you agree or disagree with that statement. The more you agree with a statement, the higher will be the number you circle. The more you disagree with a statement, the lower will be the number you circle. Please make sure that you answer EVERY ITEM and that you circle ONLY ONE number per item. This is a measure of your personal beliefs; obviously, there are no right or wrong answers.

1=STRONGLY DISAGREE (SD) 2=MODERATELY DISAGREE (MD) 3=SLIGHTLY DISAGREE (D)	4=SLIGHTLY AGREE (A) 5=MODERATELY AGREE (MA) 6=STRONGLY AGREE (SA)

		SD	MD	D	A	MA	SA
1	If I become sick, I have the power to make myself well again.	1	2	3	4	5	6
2	Often I feel that no matter what I do, if I am going to get sick, I will get sick.	1	2	3	4	5	6
3	If I see an excellent doctor regularly, I am less likely to have health problems.	1	2	3	4	5	6
4	It seems that my health is greatly influenced by accidental happenings.	1	2	3	4	5	6
5	I can only maintain my health by consulting health professionals.	1	2	3	4	5	6
6	I am directly responsible for my health.	1	2	3	4	5	6
7	Other people play a big part in whether I stay healthy or become sick.	1	2	3	4	5	6
8	Whatever goes wrong with my health is my own fault.	1	2	3	4	5	6
9	When I am sick, I just have to let nature run its course.	1	2	3	4	5	6
10	Health professionals keep me healthy.	1	2	3	4	5	6
11	When I stay healthy, I'm just plain lucky.	1	2	3	4	5	6
12	My physical well-being depends on how well I take care of myself.	1	2	3	4	5	6
13	When I feel ill, I know it is because I have not been taking care of myself properly.	1	2	3	4	5	6
14	The type of care I receive from other people is what is responsible for how well I recover from an illness.	1	2	3	4	5	6
15	Even when I take care of myself, it's easy to get sick.	1	2	3	4	5	6
16	When I become ill, it's a matter of fate.	1	2	3	4	5	6
17	I can pretty much stay healthy by taking good care of myself.	1	2	3	4	5	6
18	Following doctor's orders to the letter is the best way for me to stay healthy.	1	2	3	4	5	6

APPENDIX 4

Contents

MODEL 1

Collinearity Statistics

	Tolerance	VIF
Age at Surgery	.272	3.670
Gender	.679	1.473
Body Surface Area	.729	1.371
Diabetes	.825	1.212
Renal Disease at the time of Surgery	.873	1.145
Ejection Fraction	.600	1.666
Dyspnoea Classification	.810	1.234
Angina Classification	.770	1.299
Peripheral Vascular Disease	.654	1.529
Pulmonary Disease	.821	1.217
Parsonnet Score from Hard Data	.318	3.148
EuroSCORE	.190	5.252
Urgency of Surgery	.531	1.884
Time on the waiting list	.549	1.821
Preoperative length of stay	.647	1.546
Marital status	.455	2.197
Live Alone	.463	2.159
Employment Status	.690	1.448
Index of Deprivation	.887	1.127

Between-Subjects Factors

		Value	N
Renal Function	1.00	No renal disease	814
	2.00	Renal disease	17
Marital Status	1.00	Married/co-habiting	641
	2.00	Divorced/separated	64
	3.00	Single	43
	4.00	Widowed	83
Ejection Fraction	1.00	Poor [<30%]	63
	2.00	Fair [30-49%]	251
	3.00	Good [>49%]	517
Peripheral Vascular Disease	.00	No	712
	1.00	Yes	119

Tests of Between-Subjects Effects

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	311.012(a)	9	34.557	11.808	.000
Intercept	174.146	1	174.146	59.507	.000
Renal function	17.035	1	17.035	5.821	.016
Marital status	40.162	3	13.387	4.575	.003
Index of deprivation	38.641	1	38.641	13.204	.000
Age	109.439	1	109.439	37.396	.000
Ejection fraction	24.874	2	12.437	4.250	.015
Peripheral vascular disease	13.303	1	13.303	4.546	.033
Error	2402.644	821	2.926		
Total	36084.000	831			
Corrected Total	2713.656	830			

Parameter Estimates

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	5.120	.718	7.127	.000	3.710	6.531
[Renal function=1.00]	-1.035	.429	-2.413	.016	-1.877	-.193
[Renal function=2.00]	0(a)	.	.	.	.	.
[Marital status=1.00]	-.737	.205	-3.594	.000	-1.139	-.335
[Marital status=2.00]	-.525	.292	-1.794	.073	-1.099	.049
[Marital status=3.00]	-.857	.335	-2.555	.011	-1.515	-.199
[Marital status=4.00]	0(a)	.	.	.	.	.
Index of deprivation	.016	.004	3.634	.000	.007	.024
Age	.041	.007	6.115	.000	.028	.054
[EF=1.00]	.461	.234	1.972	.049	.002	.919
[EF=2.00]	.336	.134	2.513	.012	.074	.598
[EF=3.00]	0(a)	.	.	.	.	.
[PVD=.00]	-.373	.175	-2.132	.033	-.716	-.030
[PVD=1.00]	0(a)	.	.	.	.	.

a This parameter is set to zero because it is redundant.

MODEL 2

Collinearity Statistics

Variable	Tolerance	VIF
Age Category	.381	2.626
Gender	.638	1.568
Diabetes	.837	1.194
Body Surface Area Category	.575	1.740
Body Mass Index Category	.686	1.458
Renal Disease at the time of Surgery	.900	1.111
Ejection Fraction	.726	1.378
Dyspnoea Classification	.809	1.236
Angina Classifications	.765	1.307
Peripheral Vascular Disease	.716	1.397
Pulmonary Disease	.823	1.215
Parsonnet Risk Category from Hard Data	.374	2.673
EuroSCORE Risk Category	.298	3.355
Urgency of Surgery	.518	1.930
Time on the waiting list	.539	1.855
Preoperative length of stay	.648	1.544
Marital status	.445	2.246
Living Alone	.464	2.154
Employment Status	.685	1.461
Index of Deprivation	.893	1.120

Between-Subjects Factors

		Value	N
Age Category	.00	<51	48
	1.00	51-60	177
	2.00	61-70	301
	3.00	>70	307
Ejection Fraction	1.00	Poor [<30%]	63
	2.00	Fair [30-49%]	252
	3.00	Good [>49%]	518
Parsonnet Risk Category from Hard Data	1.00	1% low risk	242
	2.00	5% elevated risk	233
	3.00	9% significantly elevated risk	175
	4.00	17% high risk	127
	5.00	31% very high risk	56
Marital Status	1.00	Married/co-habiting	642
	2.00	Divorced/separated	64
	3.00	Single	43
	4.00	Widowed	84
Diabetes	1.00	Not diabetic	600
	2.00	NIDDM	164
	3.00	Insulin therapy	69

Tests of Between-Subjects Effects

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	360.603(a)	15	24.040	8.350	.000
Intercept	3399.787	1	3399.787	1180.837	.000
Age category	35.115	3	11.705	4.065	.007
Ejection fraction	18.618	2	9.309	3.233	.040
Parsonnet risk category	66.344	4	16.586	5.761	.000
Marital status	33.250	3	11.083	3.850	.009
Diabetes	26.067	2	13.033	4.527	.011
Index of deprivation	34.042	1	34.042	11.824	.001
Error	2352.252	817	2.879		
Total	36193.000	833			
Corrected Total	2712.855	832			

Parameter Estimates

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	7.904	.360	21.966	.000	7.198	8.611
[Agecategory=1.00]	-.504	.338	-1.493	.136	-1.168	.159
[Agecategory=2.00]	-.297	.267	-1.114	.266	-.822	.227
[Agecategory=3.00]	.183	.233	.784	.433	-.275	.641
[Agecategory=4.00]	0(a)	.	.	.	.	.
[EF=1.00]	.334	.239	1.393	.164	-.136	.804
[EF=2.00]	.348	.143	2.425	.016	.066	.629
[EF=3.00]	0(a)	.	.	.	.	.
[Parsonnet risk=1.00]	-1.004	.374	-2.684	.007	-1.739	-.270
[Parsonnet risk=2.00]	-1.182	.336	-3.516	.000	-1.842	-.522
[Parsonnet risk=3.00]	-.882	.279	-3.167	.002	-1.429	-.336
[Parsonnet risk=4.00]	-.126	.278	-.453	.651	-.671	.419
[Parsonnet risk=5.00]	0(a)	.	.	.	.	.
[Marital status=1.00]	-.646	.203	-3.182	.002	-1.045	-.248
[Marital status=2.00]	-.338	.291	-1.164	.245	-.909	.232
[Marital status=3.00]	-.719	.328	-2.190	.029	-1.364	-.075
[Marital status=4.00]	0(a)	.	.	.	.	.
[Diabetes=1.00]	-.686	.228	-3.008	.003	-1.133	-.238
[Diabetes=2.00]	-.572	.246	-2.320	.021	-1.056	-.088
[Diabetes=3.00]	0(a)	.	.	.	.	.
Index	.015	.004	3.439	.001	.006	.023

a This parameter is set to zero because it is redundant.

MODEL 3

Collinearity Statistics

Variable	Tolerance	VIF
Age at Surgery	.272	3.671
Gender	.656	1.524
Body Surface Area	.718	1.392
Diabetes	.820	1.220
Ejection Fraction	.583	1.717
Dyspnoea Classification	.802	1.247
Angina Classification	.794	1.260
Peripheral Vascular Disease	.619	1.616
Pulmonary Disease	.811	1.233
Parsonnet Score from Hard Data	.312	3.203
EuroSCORE	.186	5.363
Urgency of Surgery	.513	1.948
Time on the waiting list	.549	1.820
Preoperative length of stay	.621	1.611
Day of 5th day	.956	1.046
Marital status	.443	2.256
Living Alone	.451	2.216
Employment Status	.682	1.466
Index of Deprivation	.892	1.121

Summary of classifications (stepwise backward conditional binary logistic regression)

Observed			Predicted		
			PLOS		Percentage Correct
			> 5 days	5 days	
Step 1	PLOS	> 5 days	160	32	83.3
		5 days	54	67	55.4
	Overall Percentage				72.5
Step 2	PLOS	> 5 days	160	32	83.3
		5 days	56	65	53.7
	Overall Percentage				71.9

Observed			Predicted		
			PLOS		Percentage Correct
			> 5 days	5 days	
Step 3	PLOS	> 5 days	158	34	82.3
		5 days	54	67	55.4
	Overall Percentage				71.9
Step 4	PLOS	> 5 days	159	33	82.8
		5 days	55	66	54.5
	Overall Percentage				71.9
Step 5	PLOS	> 5 days	160	32	83.3
		5 days	58	63	52.1
	Overall Percentage				71.2
Step 6	PLOS	> 5 days	159	33	82.8
		5 days	59	62	51.2
	Overall Percentage				70.6
Step 7	PLOS	> 5 days	157	35	81.8
		5 days	60	61	50.4
	Overall Percentage				69.6
Step 8	PLOS	> 5 days	159	33	82.8
		5 days	57	64	52.9
	Overall Percentage				71.2
Step 9	PLOS	> 5 days	157	35	81.8
		5 days	57	64	52.9
	Overall Percentage				70.6
Step 10	PLOS	> 5 days	159	33	82.8
		5 days	61	60	49.6
	Overall Percentage				70.0
Step 11	PLOS	> 5 days	158	34	82.3
		5 days	57	64	52.9
	Overall Percentage				70.9
Step 12	PLOS	> 5 days	157	35	81.8
		5 days	63	58	47.9
	Overall Percentage				68.7
Step 13	PLOS	> 5 days	158	34	82.3
		5 days	67	54	44.6
	Overall Percentage				67.7
Step 14	PLOS	> 5 days	163	29	84.9
		5 days	70	51	42.1
	Overall Percentage				68.4

Variables in the equation

	B	Model Log Likelihood	Change in -2 Log Likelihood	df	Sig.of change	Odds Ratio	95.0% C.I.	
							Lower	Upper
Age	-.027	-175.452	1.069	1	0.301	.973	.924	1.025
Gender =1	.534	-175.626	1.417	1	0.234	1.705	.703	4.137
BSA	.631	-175.215	0.596	1	0.440	1.880	.378	9.348
Diabetes =1		-175.577	1.318	2	0.517			
Diabetes =2	-.314					.731	.347	1.537
Diabetes =3	-.511					.600	.207	1.741
EF =1		-177.871	5.906	2	0.052			
EF =2	-.111					.895	.203	3.937
EF =3	.721					2.057	.442	9.567
NYHA class =1		-176.900	3.965	2	0.138			
NYHA class =2	-.440					.644	.338	1.225
NYHA class =3	-.834					.434	.185	1.022
Angina class =1		-179.411	8.987	2	0.011			
Angina class =2	1.133					3.105	1.446	6.666
Angina class =3	.880					2.410	1.062	5.472
PVD =0	-.082	-174.928	0.021	1	0.884	.921	.307	2.768
Pul. =0	-.298	-175.113	0.392	1	0.531	.742	.293	1.881
Parsonnet score	.063	-176.193	2.551	1	0.110	1.065	.985	1.151
EuroSCORE	-.257	-176.827	3.818	1	0.051	.773	.592	1.010
Urgency =1	1.113	-177.499	5.163	1	0.023	3.043	1.127	8.215
Waiting list =2		-175.493	1.151	2	0.563			
Waiting list =0	.545					1.725	.424	7.024
Waiting list =1	-.009					.991	.341	2.876
Preop stay =1		-177.948	6.062	2	0.048			
Preop stay =2	.645					1.906	.832	4.366
Preop stay =3	1.393					4.026	1.211	13.383
Day of 5th day =7		-178.092	6.349	4	0.175			
Day of 5th day =1	-.360					.697	.313	1.552
Day of 5th day =2	-.060					.942	.415	2.137
Day of 5th day =3	-.884					.413	.176	.970
Day of 5th day =4	.049					1.050	.419	2.636
Marital status =4		-178.725	7.615	3	0.055			

Marital status =1	1.630					5.106	1.241	21.002
Marital status =2	1.498					4.473	.991	20.185
Marital status =3	.347					1.414	.257	7.793
Living alone =0	-.731	-175.481	1.126	1	0.289	.481	.122	1.905
Employment =1	-.474	-175.865	1.894	1	0.169	.623	.315	1.230
Index.	-.008	-175.264	0.692	1	0.405	.992	.974	1.011
Constant	-1.785					.168		

Missing Data

	N	Missing		No. of Extremes(a)	
		Count	Percent	Low	High
Index of deprivation	1005	38	3.6	0	3
BSA	1041	2	.2	7	7
EuroSCORE	1024	19	1.8	0	45
Parsonnet score	1040	3	.3	0	3
Age	1043	0	.0	4	0
Gender	1043	0	.0		
Diabetes	1041	2	.2		
Ejection fraction	1041	2	.2		
Dyspnoea	741	302	29.0		
Angina	742	301	28.9		
PVD	1041	2	.2		
Pulmonary disease	1041	2	.2		
Urgency of surgery	1041	2	.2		
Time on the waiting list	1025	18	1.7		
Preoperative stay	1043	0	.0		
Marital status	962	81	7.8		
Living alone	931	112	10.7		
Employment	518	525	50.3		
Day o f 5th postoperative day	1038	5	.5		

a Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

Tabulated Patterns of Missing Data

Number of Cases	Missing Patterns(a)																			Complete if ...(b)
	Age	Gender	Preop stay	BSA	Diabetes	EF	PVD	pulmonary	urgency	Parsonnet	Day of 5	Waiting list	EuroSCORE	Index	marital	Living alone	Dyspnoea	Angina	Employment	
313																				313
298																			X	611
96																	X	X	X	846
13														X					X	637
13														X						326
16																X			X	637
42															X	X			X	691
19															X	X	X	X	X	963
137																	X	X		450
11													X				X	X		462

Patterns with less than 1% cases (10 or fewer) are not displayed.

a Variables are sorted on missing patterns.

b Number of complete cases if variables missing in that pattern (marked with X) are not used.

MODEL 4

Collinearity Statistics

Variable	Tolerance	VIF
Age Category	.390	2.564
Gender	.665	1.504
Body Surface Area Category	.704	1.421
Diabetes	.834	1.199
Ejection Fraction	.709	1.411
Dyspnoea Classification	.802	1.247
Angina Classification	.796	1.257
Peripheral Vascular Disease	.710	1.408
Pulmonary Disease	.835	1.198
Parsonnet Risk Category from Hard Data	.374	2.673
EuroSCORE Risk Category	.294	3.406
Urgency of Surgery	.512	1.954
Time on the waiting list	.545	1.836
Preoperative length of stay	.629	1.589
Day of 5th Day	.954	1.049
Marital Status	.441	2.267
Living Alone	.454	2.204
Employment Status	.676	1.478
Index of Deprivation	.891	1.122

Summary of classifications
(stepwise backward conditional binary logistic regression)

Observed			Predicted		
			PLOS		Percentage Correct
			> 5 days	5 days	
Step 1	PLOS	> 5 days	153	39	79.7
		5 days	53	68	56.2
	Overall Percentage				70.6
Step 2	PLOS	> 5 days	156	36	81.3
		5 days	55	66	54.5
	Overall Percentage				70.9
Step 3	PLOS	> 5 days	156	36	81.3
		5 days	56	65	53.7
	Overall Percentage				70.6
Step 4	PLOS	> 5 days	155	37	80.7
		5 days	55	66	54.5

Observed			Predicted		
			PLOS		Percentage Correct
			> 5 days	5 days	
	Overall Percentage				70.6
Step 5	PLOS	> 5 days	153	39	79.7
		5 days	54	67	55.4
	Overall Percentage				70.3
Step 6	PLOS	> 5 days	156	36	81.3
		5 days	55	66	54.5
	Overall Percentage				70.9
Step 7	PLOS	> 5 days	153	39	79.7
		5 days	55	66	54.5
	Overall Percentage				70.0
Step 8	PLOS	> 5 days	151	41	78.6
		5 days	53	68	56.2
	Overall Percentage				70.0
Step 9	PLOS	> 5 days	153	39	79.7
		5 days	54	67	55.4
	Overall Percentage				70.3
Step 10	PLOS	> 5 days	152	40	79.2
		5 days	54	67	55.4
	Overall Percentage				70.0
Step 11	PLOS	> 5 days	154	38	80.2
		5 days	55	66	54.5
	Overall Percentage				70.3
Step 12	PLOS	> 5 days	154	38	80.2
		5 days	60	61	50.4
	Overall Percentage				68.7

Variables in the equation

	B	Model Log Likelihood	Change in -2 Log Likelihood	df	Sig.	Odds Ratio	95.0% C.I. for OR	
							Lower	Upper
Age category =1		-168.380	1.066	3	0.785			
Age category =2	-.320					.726	.204	2.589
Age category =3	-.613					.542	.152	1.933
Age category =4	-.564					.569	.115	2.805
Gender =1	.201	-167.942	0.189	1	0.663	1.223	.493	3.031
BSA class =1		-171.665	7.635	2	0.022			
BSA class =2	1.405					4.077	1.430	11.624
BSA class =3	1.075					2.930	.994	8.641
Diabetes =1		-168.495	1.296	2	0.523			
Diabetes =2	-.477					.621	.271	1.420
Diabetes =3	-.120					.887	.279	2.816
EF =1		-171.045	6.395	2	0.41			
EF =2	-.140					.869	.203	3.731

EF =3	.753					2.124	.507	8.896
NYHA class =1		-170.952	6.209	2	0.045			
NYHA class =2	-.497					.609	.310	1.195
NYHA class =3	-1.106					.331	.136	.808
Angina class =1		-173.048	10.402	2	0.006			
Angina class =2	1.244					3.468	1.580	7.609
Angina class =3	1.023					2.782	1.173	6.596
PVD =0	-.301	-167.983	0.271	1	0.603	.740	.239	2.296
Pulmonary =0	-.479	-168.298	0.901	1	0.342	.620	.231	1.658
Parsonnet risk =1		-171.203	6.712	4	0.152			
Parsonnet risk =2	.207					1.229	.520	2.906
Parsonnet risk =3	.321					1.379	.408	4.663
Parsonnet risk =4	-.212					.809	.174	3.756
Parsonnet risk =5	1.616					5.035	.786	32.260
EuroSCORE risk =1		-172.244	8.792	2	0.012			
EuroSCORE risk =2	-.717					.488	.186	1.281
EuroSCORE risk =3	-2.081					.125	.028	.564
Urgency =1	1.040	-169.977	4.260	1	0.039	2.828	1.023	7.815
Waiting list =2		-168.125	0.555	2	0.758			
Waiting list =0	.520					1.683	.398	7.117
Waiting list =1	.178					1.195	.409	3.496
Preop stay =1		-170.702	5.710	2	0.058			
Preop stay =2	.667					1.948	.833	4.555
Preop stay =3	1.396					4.039	1.127	14.481
Day of 5th day =7		-171.931	8.168	4	0.086			
Day of 5th day =1	-.401					.670	.295	1.522
Day of 5th day =2	-.094					.911	.386	2.150
Day of 5th day =3	-1.082					.339	.139	.827
Day of 5th day =4	.002					1.002	.386	2.595
Marital status =4		-172.551	9.407	3	0.024			
Marital status =1	1.955					7.063	1.646	30.308
Marital status =2	1.694					5.442	1.159	25.545
Marital status =3	.764					2.146	.377	12.210
Living alone =0	-.719	-168.362	1.030	1	0.310	.487	.119	1.998
Employment =1	-.498	-168.852	2.010	1	0.156	.608	.303	1.218
Index	-.006	-168.027	0.359	1	0.549	.994	.975	1.013
Constant	-2.603					.074		

MODEL 5 Continuous Variables 0.4 cut-off)

Variables in the equation

	B	S.E.	Odds Ratio	95.0% C.I.for OR	
				Lower	Upper
Day of 5th day =1					
Day of 5th day =2	.297	.392	1.346	.623	2.904
Day of 5th day =3	-.523	.418	.592	.261	1.343
Day of 5th day =4	.400	.442	1.492	.627	3.552
Day of 5th day =7	.344	.403	1.411	.641	3.105
Dyspnoea class =1					
Dyspnoea class =2	-.478	.322	.620	.330	1.166
Dyspnoea class =3	-.833	.420	.435	.191	.991
Preop stay =1					
Preop stay =2	.699	.411	2.011	.898	4.504
Preop stay =3	1.578	.585	4.845	1.540	15.242
Marital status =1					
Marital status =2	-.114	.728	.892	.214	3.720
Marital status =3	-1.196	.851	.302	.057	1.604
Marital status =4	-1.584	.714	.205	.051	.831
Urgency =0	.859	.425	2.360	1.025	5.431
EF =1					
EF =2	-.029	.742	.971	.227	4.160
EF =3	.815	.758	2.258	.511	9.979
Gender =1	.583	.435	1.791	.764	4.199
Living alone =0	-.654	.690	.520	.134	2.011
BSA	.525	.802	1.690	.351	8.140
Parsonnet score	.061	.038	1.063	.987	1.146
EuroSCORE	-.209	.108	.811	.657	1.002
Age	-.032	.026	.968	.921	1.018
Index	-.007	.009	.993	.974	1.011
Diabetes =1					
Diabetes =2	-.321	.371	.725	.350	1.501
Diabetes =3	-.485	.533	.616	.217	1.749
Angina class =1					
Angina class =2	1.138	.387	3.121	1.461	6.668
Angina class =3	.905	.416	2.472	1.093	5.589
Employment =1	.450	.345	1.568	.798	3.082
Constant	-.847	2.274	.429		

MODEL 6 Continuous Variables 0.4 cut off rerun

Variables in the equation

	B	S.E.	Odds Ratio	95.0% C.I.for OR	
				Lower	Upper
Day of 5th day =1					
Day of 5th day =2	.288	.390	1.334	.621	2.865
Day of 5th day =3	-.509	.411	.601	.268	1.345
Day of 5th day =4	.380	.437	1.462	.621	3.443
Day of 5th day =7	.337	.397	1.401	.644	3.048
Dyspnoea class =1					
Dyspnoea class =2	-.470	.317	.625	.336	1.162
Dyspnoea class =3	-.793	.413	.453	.201	1.017
Preop stay =1					
Preop stay =2	.639	.403	1.894	.860	4.173
Preop stay =3	1.659	.575	5.252	1.702	16.203
Marital status =1					
Marital status =2	-.232	.717	.793	.194	3.232
Marital status =3	-.937	.808	.392	.080	1.909
Marital status =4	-1.750	.712	.174	.043	.701
Urgency =0	.827	.419	2.286	1.006	5.191
EF =1					
EF =2	.241	.727	1.273	.306	5.292
EF =3	1.044	.743	2.841	.662	12.194
Gender =1	.629	.431	1.875	.805	4.368
Living alone =0	-.925	.676	.397	.105	1.491
BSA	.606	.788	1.832	.391	8.590
Parsonnet score	.045	.037	1.046	.973	1.124
EuroSCORE	-.143	.102	.867	.710	1.058
Age	-.033	.025	.968	.921	1.017
Index	-.005	.009	.995	.976	1.013
Diabetes =1					
Diabetes =2	-.295	.369	.744	.361	1.533
Diabetes =3	-.300	.511	.741	.272	2.017
Angina class =1					
Angina class =2	1.153	.378	3.169	1.510	6.651
Angina class =3	.866	.406	2.377	1.072	5.272
Employment =1	.315	.339	1.371	.706	2.661
Constant	-1.000	2.239	.368		

MODEL 7 Continuous Variables 0.3 cut off

Variables in the equation

	B	S.E.	Odds Ratio	95.0% C.I.for OR	
				Lower	Upper
Dyspnoea class =1					
Dyspnoea class =2	-.478	.298	.620	.346	1.112
Dyspnoea class =3	-1.041	.392	.353	.164	.761
Preop stay =1					
Preop stay =2	.498	.385	1.645	.773	3.499
Preop stay =3	1.268	.533	3.552	1.250	10.092
Urgency =1	.726	.397	2.066	.950	4.496
EF =1					
EF =2	-.151	.661	.860	.235	3.139
EF =3	.409	.654	1.505	.417	5.425
Gender =1	.753	.368	2.124	1.033	4.369
EuroSCORE	-.180	.065	.836	.735	.949
Angina class =1					
Angina class =2	1.042	.367	2.835	1.382	5.816
Angina class =3	.874	.388	2.396	1.120	5.126
Constant	-1.782	1.005	.168		

MODEL 8 Continuous Variables 0.3 cut-off rerun

Variables in the equation

	B	S.E.	Odds Ratio	95.0% C.I.for OR	
				Lower	Upper
Angina class =1					
Angina class =2	.680	.219	1.974	1.285	3.033
Angina class =3	.358	.229	1.430	.913	2.241
Dyspnoea class =1					
Dyspnoea class =2	-.200	.182	.819	.574	1.169
Dyspnoea class =3	-.434	.239	.648	.406	1.036
Preop stay =1					
Preop stay =2	.163	.228	1.177	.753	1.840
Preop stay =3	.316	.315	1.372	.739	2.544
Urgency =1	.253	.238	1.288	.808	2.053
EF =1					
EF =2	-.267	.406	.765	.346	1.694
EF =3	.245	.402	1.277	.581	2.808
EuroSCORE	-.207	.041	.813	.750	.881
Gender =1	.291	.218	1.338	.873	2.050
Constant	-.430	.608	.651		

MODEL 9 categorical variables 0.4 cut off

Variables in the equation

	B	S.E.	Odds Ratio	95.0% C.I.for OR	
				Lower	Upper
Marital status =1					
Marital status =2	-.035	.552	.966	.328	2.849
Marital status =3	-.529	.673	.589	.158	2.202
Marital status =4	-1.226	.510	.293	.108	.797
Angina class =1					
Angina class =2	1.169	.379	3.218	1.532	6.759
Angina class =3	.969	.408	2.634	1.183	5.865
Dyspnoea class =1					
Dyspnoea class =2	-.566	.313	.568	.308	1.048
Dyspnoea class =3	-1.171	.406	.310	.140	.687
BSA class =1					
BSA class =2	1.363	.477	3.908	1.534	9.956
BSA class =3	1.079	.474	2.941	1.161	7.450
Preop stay =1					
Preop stay =2	.581	.395	1.787	.825	3.875
Preop stay =3	1.388	.573	4.008	1.303	12.329
Urgency =1	.812	.412	2.253	1.004	5.057
EuroSCORE =1					
EuroSCORE =2	-.447	.296	.639	.358	1.143
EuroSCORE =3	-1.388	.464	.250	.100	.620
EF =1					
EF =2	-.231	.674	.793	.212	2.973
EF =3	.445	.663	1.561	.426	5.720
Constant	-2.376	1.005	.093		

MODEL 10 Categorical variables 0.4 cut-off re-run

Variables in the equation

	B	S.E.	Odds Ratio	95.0% C.I.for OR	
				Lower	Upper
Marital status =1					
Marital status =2	.007	.336	1.007	.521	1.946
Marital status =3	-.646	.393	.524	.242	1.133
Marital status =4	-1.060	.337	.347	.179	.672
Angina class =1					
Angina class =2	.742	.228	2.101	1.343	3.288
Angina class =3	.362	.241	1.436	.896	2.301
Dyspnoea class =1					
Dyspnoea class =2	-.300	.192	.741	.509	1.079
Dyspnoea class =3	-.473	.251	.623	.382	1.019
BSA class =1					
BSA class =2	.385	.282	1.469	.845	2.555
BSA class =3	.391	.277	1.479	.860	2.544
Preop stay =1					
Preop stay =2	.205	.246	1.227	.758	1.986
Preop stay =3	.402	.340	1.495	.768	2.909
Urgency =1	.352	.259	1.422	.855	2.365
EuroSCORE =1					
EuroSCORE =2	-.327	.193	.721	.494	1.052
EuroSCORE =3	-1.060	.295	.347	.194	.618
EF =1					
EF =2	-.049	.420	.953	.418	2.169
EF =3	.502	.415	1.652	.733	3.724
Constant	-1.112	.606	.329		

MODEL 11 Categorical Variables 0.3 cut-off

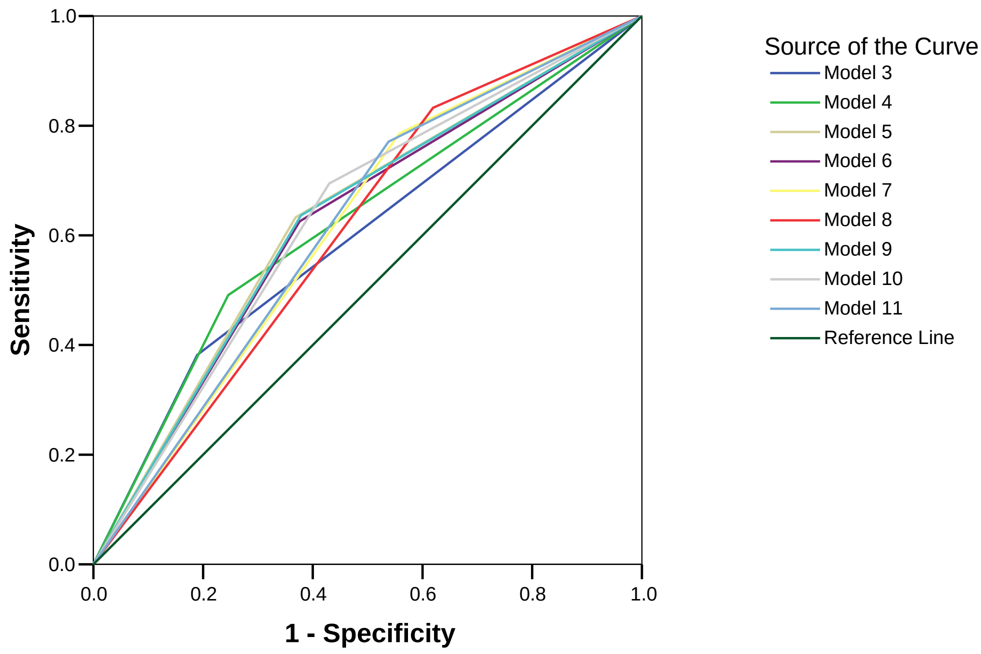
Variables in the equation

	B	S.E.	Odds ratio	95.0% C.I.for OR	
				Lower	Upper
Marital status =1					
Marital status =2	-.261	.751	.770	.177	3.358
Marital status =3	-1.191	.883	.304	.054	1.716
Marital status =4	-1.955	.743	.142	.033	.608
Angina class =1					
Angina class =2	1.244	.401	3.468	1.580	7.609
Angina class =3	1.023	.440	2.782	1.173	6.596
Dyspnoea class =1					
Dyspnoea class =2	-.497	.344	.609	.310	1.195

Dyspnoea class =3	-1.106	.456	.331	.136	.808
BSA class =1					
BSA class =2	1.405	.535	4.077	1.430	11.624
BSA class =3	1.075	.552	2.930	.994	8.641
Preop stay =1					
Preop stay =2	.667	.433	1.948	.833	4.555
Preop stay =3	1.396	.651	4.039	1.127	14.481
Urgency =1	1.040	.519	2.828	1.023	7.815
EuroSCORE category =1					
EuroSCORE =2	-.717	.492	.488	.186	1.281
EuroSCORE =3	-2.081	.770	.125	.028	.564
EF =1					
EF =2	-.140	.743	.869	.203	3.731
EF =3	.753	.731	2.124	.507	8.896
Employment =1	.498	.355	1.646	.821	3.299
Diabetes =1					
Diabetes =2	-.477	.422	.621	.271	1.420
Diabetes =3	-.120	.589	.887	.279	2.816
Day of 5^{th} day =1					
Day of 5^{th} day =2	.307	.412	1.360	.607	3.048
Day of 5^{th} day =3	-.681	.438	.506	.215	1.193
Day of 5^{th} day =4	.403	.463	1.496	.604	3.705
Day of 5^{th} day =7	.401	.419	1.493	.657	3.393
Waiting list =0					
Waiting list =1	-.342	.537	.710	.248	2.036
Waiting list =2	-.520	.736	.594	.141	2.513
Pulmonary =0	-.479	.502	.620	.231	1.658
Parsonnet category =1					
Parsonnet =2	.207	.439	1.229	.520	2.906
Parsonnet =3	.321	.622	1.379	.408	4.663
Parsonnet =4	-.212	.783	.809	.174	3.756
Parsonnet =5	1.616	.948	5.035	.786	32.260
Gender =1	.201	.463	1.223	.493	3.031
Living alone =0	-.719	.720	.487	.119	1.998
Index	-.006	.010	.994	.975	1.013
Age category =1					
Age category =2	-.320	.649	.726	.204	2.589
Age category =3	-.613	.649	.542	.152	1.933
Age category =4	-.564	.814	.569	.115	2.805
PVD =0	.301	.578	1.351	.436	4.192
Constant	-1.328	1.611	.265		

Phase I Model Development

ROC Curve

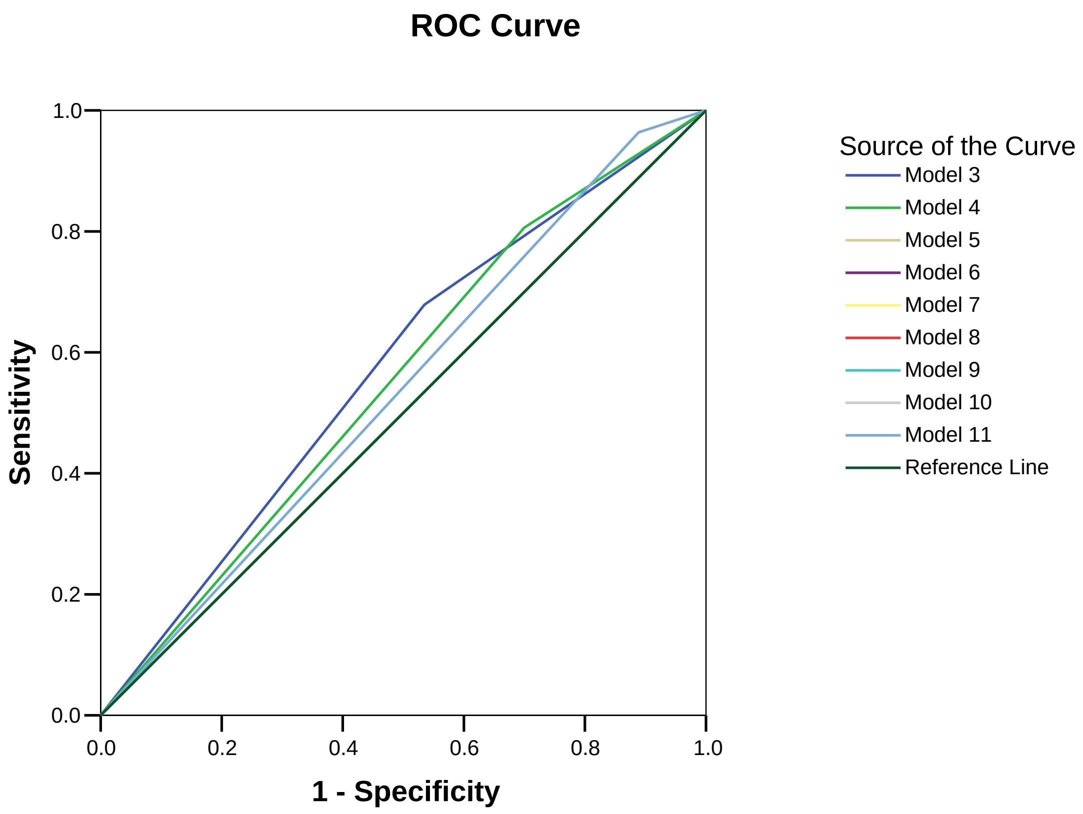


Area Under the Curve

Discharge within 5 days predicted by	Area	Std. Error	Asymptotic Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Model 3	.596	.022	.000	.552	.640
Model 4	.623	.022	.000	.579	.666
Model 5	.632	.022	.000	.589	.675
Model 6	.625	.022	.000	.582	.668
Model 7	.614	.022	.000	.572	.656
Model 8	.607	.022	.000	.564	.649
Model 9	.629	.022	.000	.586	.672
Model 10	.632	.022	.000	.590	.675
Model 11	.616	.022	.000	.574	.659
Model 12	.616	.021	.000	.574	.658

Phase II Model Validation

–



Area Under the Curve

Discharge within 5 days predicted by	Area	Std. Error	Asymptotic Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Model 3	.572	.029	.014	.516	.628
Model 4	.553	.029	.068	.497	.609
Model 5	.500	.029	1.000	.443	.557
Model 6	.500	.029	1.000	.443	.557
Model 7	.500	.029	1.000	.443	.557
Model 8	.500	.029	1.000	.443	.557
Model 9	.500	.029	1.000	.443	.557
Model 10	.500	.029	1.000	.443	.557
Model 11	.537	.029	.200	.481	.594

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