A Pilot Ontology for a Large, Diverse Set of National Health Service Healthcare Quality Indicators

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Key to Abbreviations

ACOVE	Assessing Care of Vulnerable Elders
AGREE	Appraisal of Guidelines Research and Evaluation
AMA	American Medical Association
AMIA	American Medical Informatics Association
BMA	British Medical Association
CIG	Computer-Interpretable Guideline
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CPG	Clinical Practice Guideline
CPT	Current Procedural Terminology
DAML	DARPA Agent Markup Language
DH	Department of Health
DRG	Drug Related Group
EHR	Electronic Health Record
EON	[Extensible Ontology]
GLEE	Guideline Execution Engine
GLIF	Guideline Interchange Format
GUIDE	[Guideline Framework?]
HL7	Health Level 7
ICD	International Classification of Diseases
IT	Information Technology
KA	Knowledge Acquisition
KDOM	Knowledge-Data Ontological Mapper
MEDLINE	Medical Literature Analysis and Retrieval System Online
MeSh	Medical Subject Heading

MLM	Medical Logic Module
NHS	National Health Service
NHS IC	National Health Service Information Centre for Health and Social Care
NICE	National Institute for Health and Clinical Excellence
NLP	Natural Language Processing
OWL	Web Ontology Language
PICO	Patient or Population; Intervention; Comparison; Outcome
QIPP	Quality, Innovation, Productivity and Prevention Programme
QMAS	Quality Management and Analysis System
QOF	Quality and Outcomes Framework
QUIL	Quality Indicator Language
SNOMED-CT	Systematized Nomenclature of Medicine-Clinical Terms
SQL	Structured Query Language
STEMI	ST-elevation Myocardial Infarction
SUS	Secondary Uses Service
TOVE	Toronto Virtual Enterprise
UK	United Kingdom
UMLS	Unified Medical Language System
URL	Uniform Resource Locator
US	United States
WC3	World Wide Web Consortium
WCC	World Class Commissioning

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Declaration

I hereby grant powers of discretion to the University Librarian to allow this thesis to be copied in whole or in part without further reference to me.

Abstract

Objectives: This project seeks to reduce duplication of effort in finding data for NHS healthcare quality indicators, to resolve issues identified in previous efforts to develop quality-monitoring ontologies and to identify areas for future computer-interpretable quality indicator development for the United Kingdom's Department of Health and National Health Service (NHS). Outcomes will include specification of inclusion and exclusion criteria for a set of healthcare quality indicators, along with categorisation beyond screening and prevention and identification of levels of indicator relationships

Methodology: Following an exploration of potential methods for ontology development, Methontology was the method chosen to develop the ontology. This involved a conceptual analysis to inform the development of an ontology for a 2009 set of healthcare quality indicators made available on the NHS Information Centre website. Indicators were categorised by NHS Dimension, NHS-specified clinical pathway and by United States Institute of Medicine purpose. Relationships between indicators were identified, as well as an initial set of inclusion and exclusion criteria. Protégé 3.4.1 was the platform used to develop a pilot ontology.

Results: NHS quality indicators that share some of the same criteria were made searchable, along with broader and narrower related criteria. Up to six layers of inclusion and exclusion criteria were specified and incorporated into the ontology. Search capabilities were created for indicators originating from the same source and from more than one source, along with indicators assigned to specific care pathways. It was shown that indicators have purposes other than prevention and screening, rendering Arden Syntax, intended for computer-interpretable guidelines and previously tested on a specialised set of healthcare quality indicators, unsuitable for a large, diverse set of quality indicators. A large number, 222, of quality indicators with different purposes justified the development of a separate ontology.

Conclusions: This ontology could reduce duplication of effort in finding data for NHS healthcare quality indicators. There is potential to link to components of queries currently in use in the NHS, as an interim step away from the need to develop separate queries for each indicator. Areas for future computer-interpretable quality indicator development include resolving Electronic Health Record compatibility issues and improved indicator metadata quality. The ontology could be useful to NHS indicator developers, NHS data extractors and vendors of electronic health records who supply to the NHS.

Chapter 1 - Introduction

This chapter covers the background for the research, including brief overviews of the concept of quality of healthcare, clinical practice guidelines, quality indicators and ontologies. Motivation for the research will follow the background, including issues with quality indicators in the National Health Service (NHS) and a platform to address some of these issues. The chapter will conclude with the hypothesis and objectives for this research and an outline of the thesis.

1.1 Background

1.1.2 Concept of Quality of Health Care

'Quality of Health Care' is a broad concept, described in the National Library of Medicine's Medical Subject Headings (MeSH) as "The levels of excellence which characterize the health service or health care provided based on accepted standards of quality." 'Quality indicators, Health Care', is more narrowly defined as involving measurable criteria. Introduced in 1998, it sits below the heading, 'Quality of Health Care' in the MeSH Tree Structure. The subject headings, 'Risk Adjustment' and 'Standard of Care' are narrower headings within 'Quality Indicators, Health Care'.

There are fourteen subject headings in MeSH that contain the word 'quality', with ninety-five additional headings having the word 'quality' in the scope notes. 'Quality of Health Care', introduced in 1968, sits in more than one branch of the MeSH Tree Structure and has many narrower headings,

including ‘Guideline Adherence’. Appendix 1 shows the Tree Structure for ‘Quality of Health Care’. The hierarchical Tree Structure has branches stemming from sixteen categories. The Tree Structure helps to conceptualise different aspects of healthcare quality, with narrower and same level components. ‘Clinical Practice Guidelines’ (‘Guidelines as Topic’) and ‘Quality Indicators, Health Care’ are two related aspects of healthcare quality.

1.1.3 Clinical Practice Guidelines

In 1992, The United States (US) Institute of Medicine published a highly cited report, defining clinical practice guidelines (CPGs) as "systematically developed statements to assist practitioners and patient decisions about appropriate health care for specific circumstances" (Field and Lohr 1992). Guidelines may be developed at local, regional, national, or international levels (Woolf et al. 1999, Ollenschlager et al. 2004). A major goal of CPGs is to improve patient outcomes.

CPGs can also be used to:

- Address inconsistencies in quality of health care
- Assist with health care policy development
- Foster professional consensus and fellowship

Drawbacks of CPGs include:

- Inapplicability to some individual patients
- Possible misinterpretation
- Poorly written guidelines
- Outdated guidelines

- Clinicians may resent outside interference with their decision-making
- Lack of access to or awareness of appropriate CPGs
- Lack of resources for implementation

Clinical guidelines are sometimes confused with clinical pathways, consensus statements, or protocols. “A protocol is a set of systematically developed statements specifying the roles and dependencies between planned activities as part of a plan” (Román 2007). A consensus statement is (NICE 2013) “A statement based on the collective views of a body of experts.“ This may or may not be incorporated into a CPG.

1.1.4 Quality Indicators

Quality indicators are designed to assess changes in quality of health care. Campbell et al. (2002) state that indicators describe the structure, process or outcomes of care. Quality indicators differ from CPGs in that CPGs are designed to assist with clinical decision-making. While CPGs are intended to improve patient outcomes, quality indicators measure health care outcomes. Quality indicators also assist with assessing the effectiveness of quality improvement programmes, pay for performance and public accountability (Institute of Medicine 2006). Table 1.1 (Walter et al. 2004) shows the difference between CPGs and quality indicators (or performance measures).

Characteristics	Practice Guidelines	Performance Measures
Definition	Sources of recommendation to be applied prudently based on clinical experience	Quantitative tools (eg, rates, percentages) that indicate performance related to a specific process or outcome
Intention	Consolidate information to reduce gaps between scientific knowledge and clinical practice	Measure the quality of medical care

Language	Flexible: acknowledge the "gray zone" of uncertain appropriateness	Rigid: provide specific criteria for which practices are "right" and "wrong"
Complexity	Acknowledge medical complexity and patient preferences	Simplistic algorithms that provide clear scoring instructions for processes that can be measured practically
Accountability	Advisory	Mandatory: assign penalties or rewards based on performance

Table 1.1. **Characteristics of Practice Guidelines vs Performance Measures** (Walter et al. 2004)

EHR data accuracy, completeness and comparability are factors that may interfere with successful measurement of quality (Chan et al. 2010). Variations in health care settings, populations served, health conditions, data elements and EHR systems are some of the challenges in developing quality indicators. Failure to assess illness severity of the population audited for adherence, failure to distinguish screening from diagnostic procedures and lack of accounting for patient preferences or clinician judgment when scoring performance measures can also interfere with successful application of quality indicators (Walter et al. 2004). O'Connor and Neumann (2006) point out that the cost of incapacity benefits should sometimes be factored into measurement of outcomes. Quality indicators will be explored further in Chapter 2.

1.1.5 Ontologies

"Ontology" is defined in a general dictionary as "a branch of philosophy concerned with the nature of being [b]y 'the nature of being' " (Allen 2007). The field of Health Informatics has embraced this term as a system for

organising concepts. An ontology is an “explicit specification of a conceptualization” (Gruber 1993b).

Ontologies differ from relational databases in that they are more flexible (Klein et al. 2001), with the ability to expand, and have less constraints on data structures (Gruber 2009, Horrocks (2008). Ontologies focus on possibilities, while relational databases concentrate on definite structures. This makes ontologies more suitable for linking data from different sources (Gruber 2009).

A practical way to explain biomedical ontologies is to examine some of their functions. Functions of ontologies have been portrayed in different ways (Bodenreider 2008, Rubin et al. 2008), some of which appear to be arbitrary. Controlled vocabularies and the facilitation of data exchange are examples of functions of ontologies. Ontologies will be further explored in Chapter 2.

1.2 Motivation

1.2.1 Need for Improvement in Healthcare Quality Monitoring

In the United Kingdom’s National Health Service, quality indicators are frequently measured electronically by using queries and data extraction, with very little support of conceptually modelled ontologies that may help to facilitate quality monitoring. NHS Trusts must supply data to show whether they are complying with NHS quality indicators. Electronic Health Record vendors should consider elements of healthcare quality indicators when designing or making changes to EHRs. RAND Europe (2012) has noted that interoperability interfered with the success of the UK Department of Health’s

2009-2012 integrated care pilots. Improved access to the quality indicators themselves, along with components of the indicators, may improve interoperability and data extraction.

It has been shown that queries do not always adequately translate the quality indicators (Morris et al. 2004). Mabotuwana and Warren (2010) explain that relying on individual queries complicates the addition of new criteria to quality indicators. Baker et al. (2007) found that the use of queries increased the number of false positives for exclusion criteria. Benin et al. (2011) found that relying on clinical coding to measure quality indicators is less reliable than a more iterative process. Persell et al. (2010) explain that automated data capture may miss clinical detail. They recommend the inclusion of exceptions to quality indicators in the recording of normal clinical workflow. Chan et al. (2010) advocate for research into attributes of quality indicators to support electronic health record compatibility.

1.2.2 Relationship between Clinical Practice Guidelines and Quality Indicators

As discussed in section 1.1.5, ontologies are useful for linking data from different sources (Gruber 2009). While much research has been published on ontologies for computer-interpretable guidelines (Wang et al 2002, Wang et al 2003, Shahar et al 2004, Bernstein and Anderson 2008, White and Roudsari 2011, Peleg 2011), research related to computer-interpretable quality indicators has lagged behind. Useful ontology research for computer-interpretable quality indicators could identify attributes and facilitate tailoring of

queries by identifying relationships between indicators and their component parts.

Quality indicators and clinical practice guidelines are part of a set of health care quality tools intended to improve health care. There are many similarities between quality indicators and clinical practice guidelines, often involving physical measurements and time-sensitive data. Quality indicators are frequently derived from clinical practice guidelines (Mertz 2009, Kotter 2012). As quality indicators are increasingly used to evaluate clinical practice, it is useful to determine whether the application of guideline modelling ontologies may facilitate the development of computer-interpretable quality indicators (Jenders 2008). Additionally, it may be useful to develop a separate ontology for quality indicators.

Arden Syntax, a precursor to GLIF, an ontology developed for clinical practice guidelines, has been somewhat successfully applied to a small, specific set of quality indicators (Jenders 2008). There is room for improvement in the ontology and in testing on a larger, more diverse set of indicators. This is, in part, due to Arden Syntax's having been designed to support computer-interpretable screening and prevention guidelines, rather than other guideline categories (Ohno-Machado et al. 1998). Although many quality indicators are based on clinical practice guidelines, a diverse set of healthcare quality indicators is likely to cover more categories than just screening and prevention and will show whether a more flexible ontology is warranted.

1.2.3 Benefits of Ontology Development

Finding commonalities, such as organisational structure (eg, Next Stage Review pathway), process (eg, screening and prevention) and hierarchical relationships, among a large set of quality indicators can reduce the time and effort needed to find data for the quality indicators. Integration of inclusion and exclusion criteria into an ontology will resolve a semantics issue previously identified with respect to computerisation of quality indicators (Surján et al. 2006, Baker et al. 2007, Persell et al. 2010).

NHS Trusts will be able to use this ontology to reduce administrative time required to identify relevant quality indicators for specific departments. Because quality indicators come from different sources, duplication of effort is often required to find indicators specific to clinical areas. Access to commonalities between different types of indicators, such as age groups, previous history of a clinical condition or test results relevant to a range of clinical conditions may speed the quality monitoring process and enable tailored queries to extract data for quality indicators. Identification of layers of inclusion and exclusion criteria will also facilitate tailored queries and reduce duplication of effort finding data. Patient data that should be excluded from indicator reporting will be easier to identify, as will patient data which should be included in indicator reporting. Instead of browsing through lists of quality indicators, issued by different government entities, Trusts will be able to identify related indicators and indicator components, thus reducing effort in the quality-monitoring process. Organisations that develop queries for NHS

quality indicators will be able to separate components of queries and code or otherwise relate the components to relevant components of indicators.

This ontology should be used to inform the development of metadata for future sets of healthcare quality indicators. The ontology will allow for specification of inclusion and exclusion criteria and specification of relationships between indicators, along with specification beyond screening and prevention. The ontology can serve as a guide for EHR and quality indicator developers, highlighting information that is either vital to include in health records or warning indicator developers that indicators need to be worded in such a way that facilitates data extraction. This document-centric approach (Sonnenberg and Hagerty 2006) is useful in that it does not require EHR compatibility. It is instead intended as a stage toward EHR compatibility.

1.2.4 Development Platform

Protégé, a freely available ontology development platform, has been selected to create the ontology. Protégé is used to describe concepts, including their properties, attributes and constraints (Noy and Tu 2003). Instances of the concepts are identified after the concepts, properties, attributes and constraints have been initially specified, with revision taking place as needed throughout the development process. In Protégé 3.4.1, the version of Protégé chosen for this ontology, concepts are specified as ‘classes’ and properties are specified as ‘slots’. Classes may have subclasses and slots may have subslots, with subclasses and subslots inheriting the properties or attributes of their parent versions.

Protégé 3.4.1 is frames-based, with tabs to differentiate work areas for classes; slots; instances; forms to enter instances; and queries. Buttons and widgets can be used to manipulate the classes, slots, forms and queries. Further information on ontology development platforms is available in section 2.4.3.5 Ontology Development Platforms.

1.2.5 Motivation Summary

This project will facilitate computer-interpretable quality indicators by specifying an initial set of inclusion and exclusion criteria from a large, diverse set of quality indicators (NHS Information Centre 2009a) from an ontology development perspective. The project will list the indicators by Institute of Medicine category (Field and Lohr 1992), investigating whether certain categories of quality indicators warrant specific capabilities in an ontology. Specification of relationships is an integral part of ontology conceptualisation and development. This research project may therefore contribute to closing the research gap regarding interoperability in ontology development for health care quality monitoring by exploring attributes of and relationships between health care quality indicators. The literature review will also serve as a contribution to the field of health informatics by exploring quality monitoring via electronic health records.

1.3 Hypothesis and Objectives

1.3.1 Hypothesis

The hypothesis of this research is that the conceptualisation stage of ontology development for a large set of health care quality indicators can facilitate specification of inclusion and exclusion criteria, along with categorisation beyond screening and prevention and identify levels of indicator relationships. Stated as two research questions, this translates to:

1) What attributes of health care quality indicators influence the development of an ontology that emphasises specification of inclusion and exclusion criteria, along with specification beyond screening and prevention?

2) What relationships between health care quality indicators identify complexity of indicator relationships?

1.3.2 Objectives

1. To identify relationships in a large, diverse set of quality indicators
2. To identify layers of inclusion and exclusion criteria for a large, diverse set of quality indicators
3. To determine the attributes of quality indicators most suited to ontology coverage
4. To determine whether there any features of quality indicators that do not need an ontology to facilitate quality-monitoring
5. To develop a preliminary ontology for a large, diverse set of quality indicators

Justification for the first and second objectives appear in section 2.6.3.5, Challenges for Computer-Interpretable Quality Indicators, in the literature review. Established approaches for developing computer-interpretable quality

indicators will be covered in section 2.6.3, Computer-Interpretable Quality Indicators, in the literature review, with notable features described in Chapter 6. The third and fourth objectives are justified in sections 1.2.1, Need for Improvement in Healthcare Quality Monitoring, 2.6.3.5, Challenges for Computer-Interpretable Quality Indicators, and 2.7, Summary, of the literature review, respectively, and in section 3.2.3, Conceptualisation, of the Methodology chapter.

1.3.3 Outline of the Thesis

Chapter 2 will offer a review of the literature related to the concept of quality, clinical practice guidelines and quality indicators, with respect to computer interpretability and ontologies. The search strategy and statements will be introduced, along with the objectives for the review. The concept of health care quality will be explored. An overview will be provided of clinical practice guidelines and the use of ontologies to facilitate their computer interpretability. The development and use of quality indicators will be detailed, along with use of ontologies to facilitate their computer interpretability. Popular methods for developing ontologies will be identified, along with the reason for the chosen method. Procedures for evaluating ontologies will be described, with relevant evaluative strategies selected for application to this research.

Chapter 3 will describe the method for this project, explaining how it was applied. Chapters 4 and 5 will describe the results of the project. A discussion and analysis will follow in Chapter 6. Chapter 7 will offer conclusions and Chapter 8 will provide recommendations for further research.

1.4 Summary

This chapter has explored the background and motivation for this research, giving brief overviews of the concept of quality, clinical practice guidelines, quality indicators and ontologies. It has also presented the hypothesis and objectives, followed by an outline of the thesis. The next chapter will summarise the literature review leading to this project.

Chapter 2 Review of the Literature

2.1 Objectives

The objectives for this literature review were:

1) To assess whether developing an ontology for health care quality indicators will make a significant contribution to health informatics research;
2) To provide an overview of research on the development of ontologies for computer-interpretable guidelines;
3) To provide an overview of research on the development of ontologies for health care quality indicators;
4) To provide background information on clinical practice guidelines, quality indicators and ontologies;
5) To assess approaches to ontology development;
6) To explore methods for evaluating ontologies.

2.2 Search Strategy

A review was conducted in 2012, to identify articles with the concepts of:

1) Health Care Quality Indicators
2) Clinical Practice Guidelines
3) Computer Interpretability
4) Ontologies

Database searches in PubMed, CINAHL, Cochrane, and Web of Science were supplemented by hand-searches of reference lists of the selected

articles. The MeSH terms used to search for the concepts of computer-interpretability and healthcare quality indicators were: ***Medical Records Systems, Computerized*** AND ***Quality Indicators, Health Care***. 'Ontologies' was not a MeSH term at the time of the search and is currently limited in scope to biological ontologies. The concept of ontologies was entered as a truncated key word (ontolog*) and covered, in part, by the MeSH term, ***Medical Records Systems, Computerized***. An additional search was conducted in City University's library catalogue, for general books on ontologies, using the Subject word 'ontologies'.

The 2012 review followed a 2009 search of the same databases, which included the concept of clinical practice guidelines. The MEDLINE search statement was:

("quality assurance, health care"[Mesh] OR "quality control" OR audit OR "Guideline Adherence"[Mesh] OR compliance OR reminder systems[mesh] OR reminders) AND ("Medical Records Systems, Computerized"[Mesh]) OR EMR's OR "Electronic Medical Records" OR EPR's OR "Electronic Patient Record*" OR EHR's OR "Electronic Health Records" OR "clinical coding" OR "forms and records control"[mesh]) AND ("Vocabulary, Controlled"[Mesh] OR ontolog* OR thesaur*) AND ("practice guidelines as topic"[Mesh] OR "clinical practice guidelines" OR cpgs).

The Related Articles search link was used in PubMed for relevant articles. The US National Center for Biomedical Ontology, DAML (DARPA Agent Markup Language) Library and OpenClinical websites were browsed, with relevant external links or references noted (Wynden et al. 2010, Peleg et al. 2004a). Information selected from non-permanent resources, eg, web sites,

was verified, where possible, in permanent resources. Where this was not possible, it was noted as such.

PubMed searches were stored in NCBI's database and set to send updates. Articles published in languages other than English were excluded. When an author or group of authors had published more than one article on substantially the same topic, the most recent article was selected. Primary literature was reviewed as a priority, with grey literature included if it met all other criteria. Review articles and commentary were marked for background reading.

The authors of relevant articles were searched under a 'Cited Articles' search in Web of Science and/or Google Scholar for follow-up articles by the original first author. Information selected from non-permanent resources, eg, web sites, was verified, where possible, in permanent resources. Where this was not possible, it was noted as such.

PICO (Patient or Population; Intervention; Comparison; Outcome) is one framework commonly used to help clinical researchers to create answerable clinical questions. PICO works well for identifying clinical questions. It does not always work well in specifying non-clinical questions. The question for the 2012 literature search could be stated as: "How are ontologies being used to improve computer interpretability of health care quality indicators?" The question for the 2009 literature search could be stated as: "How are ontologies being used to facilitate audit of clinical practice guidelines via

electronic health records?" These are not clinical questions and do not fit well in the PICO framework.

2.2.1 Inclusion/Exclusion Criteria

Because ontologies are a relatively new area in the field of health informatics and opinions vary as to what constitutes an ontology in this field (Jones et al.1998, Bodenreider 2008, Rubin et al. 2008, Horrocks 2008, Klein et al. 2001, Grabar et al. 2012), articles were selected from the 2012 results if their titles or abstracts focused on the development of computer-interpretable healthcare quality indicators or an ontology for healthcare quality indicators. Titles and abstracts of the 2009 results were reviewed regarding the inclusion/exclusion criteria of whether the article was about using ontologies to facilitate assessment of compliance with clinical practice guidelines via electronic health records. Articles about single reminder systems were excluded, as clinical practice guidelines tend to be multi-faceted. When an author or group of authors had published more than one article on substantially the same topic, the most recent article was selected. Articles for the literature review for this thesis were ranked by the number of the following concepts that they covered: Health Care Quality Indicators, Clinical Practice Guidelines, Computer Interpretability, and Ontologies. The next sections will cover the concepts of Quality of Healthcare; Ontologies, including approaches to development and evaluation; Clinical Practice Guidelines, including computer-interpretable guidelines; and Quality Indicators, including computer-interpretable quality indicators.

2.3 Quality of Healthcare

2.3.1 Definition

In a classic article, Donabedian (1966) describes quality as little more than a value judgement. He goes on to define healthcare quality as “a reflection of values and goals current in the medical care system and in the larger society of which it is a part.”

2.3.2 Brief History

The Hippocratic Oath (translated by North 2002) demonstrates the dedication of physicians to quality of practice. The existence of doctors for members of the public has been documented from the fifth century, BC. These posts, granted on a competitive basis, show that quality of care was a consideration, though selection was largely based on public reputation. Contracts for health care provided by physicians provides a picture of commitment to health care quality during Medieval times (Sistrunk 1993). There was as yet no systematic method of evaluating the quality of health care. Medical schools and universities became recognised as a formal route to clinical competency in the twelfth and thirteenth centuries.

In the early eighteenth century, Francis Clifton published “The state of physick, ancient and modern, briefly considered with a plan for the improvement of it” (Tröhler 2011). This was one of the first calls for the medical community to use numbers to assess the quality of health care. Tables of results of small pox inoculations were circulated in 1722.

In 1803, Sir Thomas Percival attempted to persuade colleagues of the benefits of establishing a hospital registrar to improve the quality of care. Although his fellow English physicians were not convinced, his work informed the American Medical Association's (AMA) 1847 first Principles of Medical Ethics. During the 1850's, Florence Nightengale collected data to improve clinical outcomes. She developed a model hospital statistical form to collate data and statistics (Darr 2007).

In the early nineteenth century, a Boston surgeon, Earnest Codman, began organising conferences focusing on discussions of morbidity and mortality, leading to the concept of outcomes management in patient care (Darr 2007). The American College of Surgeons' Hospital Standardization Program, established in 1917, included a requirement to keep medical records of patient care (Luce et al. 1994). This programme led to the 1952 formation of the Joint Commission on Accreditation of Hospitals, a collaboration between the American College of Surgeons, the American College of Physicians, the American Hospital Association, the AMA, and the Canadian Medical Association.

During the 1920's, Walter Shrewhart developed a technique called 'Statistical Process Control', the precursor to Continuous Quality Improvement (Darr 2007), popular in the 1980's. Shrewhart's technique emphasized consistency and similarity. The concept of continuous quality improvement has been recycled under various euphemisms ever since.

2.4 Ontologies

2.4.1 Definition

The definition of ontologies has not stabilised in the field of Health Informatics. This is, perhaps, due to its newness to the field. Gruber (1993b) describes an ontology as a "specification of a representational vocabulary for a shared domain of discourse — definitions of classes, relations, functions, and other objects" and also as "an explicit specification of a conceptualisation" (Gruber 1993b). Guarino and Giaretta (1995) describe the meaning of ontology as "vague" and identify seven interpretations. Other than original use of the term "ontology" in the field of philosophy, the differences relate to semantic versus syntax interpretations, formal versus informal interpretations, and interpretations of logic, theory, specification and conceptualisation.

Jones et al. (1998) define an ontology as a 'domain model'. Klein et al. (2001) further state that "ontologies provide a *shared and common* understanding of a domain that can be communicated between people and heterogeneous and distributed application systems." Bodenreider (2008) uses the terms 'ontologies' and 'terminology' interchangeably, though does not rule out other types of ontologies. Grabar et al. (2012) explore varying interpretations of the meaning of 'terminology' and 'ontologies' and suggests that they are part of a continuum. Rubin et al. (2008) describe ontologies in a similar manner to the description of a relational database; as the "specifications of the entities, their attributes and relationships among the entities in a domain of discourse. Horrocks (2008) explains that an ontology is " a model of some aspect of the world and introduces vocabulary relevant to domain", often including names

for classes and noting relationships, …it "specifies intended meaning of vocabulary, typically formalized using a suitable logic, …and consists of two parts (axioms describing the structure of the model and facts, describing some concrete situation)". While these definitions have similarities, often involving representational descriptions of a domain, they may be confused with the description of a relational database.

Horrocks (2008) distinguishes between ontologies and relational databases by explaining that relational databases present a 'closed world' view, with missing information considered invalid, while ontologies offer an 'open world' view, with missing information interpreted as unknown and possibly valid. Ontologies are more flexible than relational databases and therefore more suited to linking data from different sources (Gruber 2009). Horrocks also notes that ontologies are capable of making inferences (reasoning). Horrocks' interpretation may conflict with those that include terminologies, as terminologies are not known for their ability to reason. In a guide used to support learning Protégé, used in this research, Noy and McGuiness ([2002]) acknowledge that there are contradicting definitions of ontologies in the published literature. They go on to state:

> "For the purposes of this guide, an **ontology** is a formal explicit description of concepts in a domain of discourse (**classes** (sometimes called **concepts**)), properties of each concept describing various features and attributes of the concept (**slots** (sometimes called **roles** or **properties**)), and restrictions on slots (**facets** (sometimes called **role restrictions**)). An ontology, together with a set of individual **instances** of classes, constitutes a **knowledge base**. In reality, there is a fine line where the ontology ends and the knowledge base begins. (Noy and McGuiness [2002])."

2.4.1.1 Two Functions of Ontologies related to Quality in Health Informatics

Ontologies serve different functions in Health Informatics. Examples of the functions of terminologies and facilitation of data exchange among applications are given in this section. Terminologies are emphasised because they have a much longer history.

2.4.1.1.1 Terminologies

Terminologies may serve different purposes. Medical reference terminologies are used to organise complex clinical concepts. The Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT) is an example of a reference terminology (Kanter et al. 2008). Medical interface terminologies are more narrowly intended to support digital recording of or access to patient-related information. Daniel-Le Bozac et al. (2009) describe the importance of interface terminologies in clinical statements and the need for interface terminologies to map to reference terminologies. Classification systems, such as ICD-10 and CPT are used for secondary purposes, eg, reimbursement and public health reporting. They can then sometimes be mapped to other terminologies or classification systems (American Medical Informatics Association and American Health Information Management Association Terminology and Classification Policy Task Force [2006]). There is conflicting literature on types of terminologies (Daniel-Le Bozec et al. 2007, American Medical Informatics Association (AMIA) and American Health Information Management Association (AHIMA) Terminology and Classification Policy Task Force 2006). Daniel-Le Bozec et al. (2007), describe the International Classification of Diseases as a reference terminology, while the

AMIA and AHIMA Terminology and Classification Policy Task Force (2006) distinguish between terminologies and classification systems, explains that classification systems, including ICD, are more general and lack the clinical detail of terminologies.

2.4.1.1.2 Facilitating Data Exchange Among Applications

Ontologies can be used to facilitate data exchange among applications, such as computerised clinical practice guidelines and electronic health records. Ontologies are useful to facilitate data exchange because they can be used to describe data from different sources. Figure 2.1 shows an example of data exchange among applications. The domain ontology and upper ontology link to HL7 and an external database, enabling communication between different systems. Upper ontologies are very broad categories (eg, Thing) which can cross domains. Upper ontologies are not always shown as separate from domain ontologies.

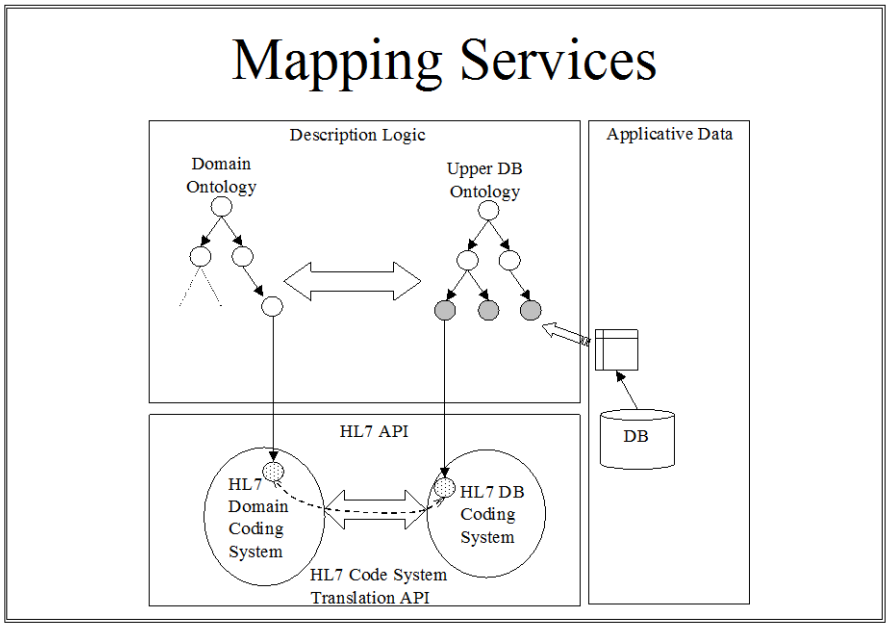

Figure 2.1: This is an example of how ontologies can facilitate data exchange among applications (Correndo and Terrenziani 2004).

2.4.2 Brief History

In the 17th century, an effort to compile accurate health statistics became known as “the Bills of Mortality.” Health authorities in London used a standard list of about 200 causes of death, to organise data. The list was later integrated into the International Classification of Diseases (ICD), now maintained by the World Health Organization. Linnaeus also began formalising the biological relations among species (Bodenreider 2008).

2.4.3 Approaches to Ontology Development

Jones et al. (1998) describes two approaches to ontology development: stage-based and evolving. Unless otherwise stated, steps in stage-based approaches are not repeated. TOVE (Toronto Virtual Enterprise) and

Enterprise are two established examples of the stage-based approach. Evolving approaches are more flexible, allowing for repetition of steps and with less emphasis placed on order of steps. Methontology and IDEF5 are two popular examples of the evolving approach.

2.4.3.1 Stage-based Approaches

2.4.3.1.1 TOVE

TOVE (Toronto Virtual Enterprise) involves 6 stages (Jones et al.1998):

"(1) *motivating scenarios*: the start point is a set of problems encountered in a particular enterprise, which are often in the form of story problems or examples.
(2) *informal competency questions*: requirements of the ontology, based on the motivating scenario, described as informal questions that an ontology must be able to answer; this phase acts as an evaluation on the ontological commitments made in the previous stage.
(3) *terminology specification*: the objects, attributes and relations of the ontology are formally specified (usually in first order logic).
(4) *formal competency questions*: the requirements of the ontology are formalised in terms of the formally defined terminology….
(5) *axiom specification*: axioms that specify the definition of terms and constraints on their interpretations are given in first-order logic, guided by the formal competency questions as the axioms must be necessary and sufficient to express the competency questions and their solutions.
(6) *completeness theorems*: an evaluation stage which assesses the competency of the ontology by defining the conditions under which the solutions to the competency questions are complete."

TOVE is implemented with C++ and Prolog (Bullinger 2008). It is intended to support deductive reasoning in distributed enterprise models (Fox 1992).

2.4.3.1.2 Enterprise

The Enterprise model involves 4 stages (Jones et al.1998):

"(1) *identify purpose*: determines the level of formality at which the ontology should be described.
(2) *identify scope*: a "Specification" is produced which fully outlines the range of information that the ontology must characterise. This may be done using motivating scenarios and informal competency questions, as in

TOVE or by “brainstorming and trimming” i.e. produce a list of potentially relevant concepts and delete irrelevant entries and synonyms.

(3) *formalisation*: create the “Code”, formal definitions and axioms of terms in the Specification.

(4) *formal evaluation*: the criteria used may be general, …, or specific to a particular ontology, such as checking against purpose or competency questions. This stage may cause a revision of the outputs of stages 2 and 3.”

The Enterprise model focuses on people and their interactions, and on organisations (Dietz 2006).

2.4.3.2 Evolving Approaches

2.4.3.2.1 Methontology

The nine components of Methontology are: specification, knowledge acquisition, conceptualisation, integration, formalisation, implementation, evaluation, documentation, and maintenance. Knowledge acquisition, evaluation, and documentation are applied throughout each component. The components are further explained as follows:

Specification involves explaining the intended use of the ontology, along with the intended audience, and scope of terms to be represented.

Knowledge Acquisition takes place during the specification process and may continue during other processes. Knowledge Acquisition often involves literature reviews and interviews.

Conceptualisation is the informal representation of domain terms in the form of concepts, instances, verbs, relations, and properties.

Formalisation uses frames-oriented or description logic systems to model the ontology.

Integration attempts to address a common standard for ontologies, by incorporating definitions from other ontologies.

Implementation occurs when the ontology is translated into a formal language.

Evaluation involves assessing the ontology for completeness, consistency and redundancy.

Documentation entails the selection and organisation of documents produced during the entire process.

Maintenance is the continued assessment and development of the ontology, in line with the specification.

Methontology supports ontology development at the conceptual level, with less focus on the implementation or post-development level (Semantic Web 2012).

2.4.3.2.2 IDEF5

IDEF5 (Integrated Definition for Ontology Description Capture Method) has 5 components (Jones et al.1998):

"(1) *organising and scoping*: establishes the purpose, viewpoint, and context for the ontology development project. The purpose statement provides a set of "completion criteria" for the ontology, including objectives and requirements. The scope defines the boundaries of the ontology and specifies parts of the systems that must be included or excluded.
(2) *data collection*: the raw data needed for ontology development is acquired using typical KA [Knowledge Acquisition] techniques, such as protocol analysis and expert interview.
(3) *data analysis*: the ontology is extracted from the results of data collection. First, the objects of interest in the domain are listed, followed by identification of objects on the boundaries of the ontology. Next, internal systems within the boundary of the description can be identified.
(4) *initial ontology development*: a preliminary ontology is developed, which contains *proto-concepts* i.e. initial descriptions of kinds, relations and properties.
(5) *ontology refinement and validation*: the proto-concepts are iteratively refined and tested. This is essentially a deductive validation procedure

as ontology structures are “instantiated” with actual data, and the result of the instantiation is compared with the ontology structure.

IDEF5 uses both graphical and structured text languages (Grover 2000). IDEF is most commonly used for US military projects (KBSI [2000]).

2.4.3.3 Comparison of Approaches to Ontology Development

There are many similarities between the different approaches to ontology development described in this chapter, including specification of terms and their definitions. All of the approaches have evaluative components. The Stage-based approaches are more proscriptive, with known scenarios and requirements established towards the beginning of the ontology development. TOVE is problem-based, while Enterprise emphasises the essence or intention of an organisation, rather than its structure. Like TOVE, the Enterprise model is intended to support enterprise organisations. The Enterprise model allows more flexibility in developing the specification, as brainstorming is acceptable. The Enterprise model also allows more flexibility in evaluation, as the criteria may be general or specific to the ontology (eg, competency questions). TOVE requires two types of competency questions: formal and informal.

The Evolving approaches are suitable for developing ontologies when scenarios and requirements are not necessarily known. Both Methontology and IDEF5 involve knowledge acquisition, which is not a component of the Stage-based approaches. Methontology appears more thorough than IDEF5,

involving documentation and maintenance. Both Methontology and IDEF5 allow for overlap and repetition of steps.

2.4.3.4 Justification of Use of Methontology

The decision to use a modified version of an evolving prototype methodology, Methontology, was informed by Jones' et al. (1998) seminal review of methods for ontology development. Jones et al. note that while stage-based approaches are useful when requirements are clear at the outset, an evolving prototype, such as Methontology, allows more flexibility in development. The disparate nature of different clinical areas covered by the selected set of quality indicators, coupled with the potentially different nature of quality indicators from different sources, meant flexibility was crucial to the development of the proposed ontology. Methontology is also suitable for non-expert ontologists (Fernandez-Lopez et al.1999) and is described as the most 2.4.4 mature methodology of several reviewed by Corcho et al. (2003). Stage-based approaches, such as TOVE, would not work for an undefined model, with unknown components and attributes.

2.4.3.5 Ontology Development Platforms

While ontologies are encoded using expression languages, such as OWL (Web Ontology Language) and OBO (Open Biomedical Ontologies) (Popescu and Xu 2009), they are generally developed with the aid of editorial tools. Denny (2004a) compared ninety-six ontology editors, assessing categories such as features and limitations, base language, availability via the Internet

and the ability to perform consistency checks. Two features he did not assess were cost and ease of use for new ontology developers, important considerations for this project. He singles out Protégé in a benchmarking sense, to illustrate that ontology editor features are still evolving, and refers to it as a very capable tool (Denny 2004b). He suggests that it may be useful to use more than one ontology development tool, depending on features needed to develop the ontology, and that suitable ontology development tools may very, depending on the chosen domain. He acknowledges a collective desire for ontology editors that are easy to use, for non-expert ontology developers.

Many ontology editors lack long term availability and support. The WC3 (World Wide Web Consortium) (WC3 2014) lists ten ontology editors, including Protégé, NeOntoolkit, SWOOP, Neologism, TopBraid Composer, Vitro, Knoodl, Anzo for Excel, OWLGrEd, and Fluent Editor. Of these ten editors, SWOOP and Knoodl are no longer available at the URLs shown on the WC3 website. Protégé is by far the most popular of the freely available ontology editors (Keramaris 2014).

2.4.3.5.1 Justification of Selection of Protégé 3.4.1

Protégé is a well known ontology editor, popular with academic and business developers (Stanford Center for Biomedical Informatics Research.2014a). The availablility of educational and supporting information, including a user discussion group, contributed to the decision to use Protégé for this project. Popescu and Xu (2009) recommend Protégé, due to its free availability and its being noted in OWL tutorials. Learning about ontologies through frames-

based tutorials (Sachs 2006, Stanford Center for Biomedical Informatics Research 2014c) influenced the decision to use a frames-based version of Protégé.

Protégé 3.4.1 and Protégé 4.0 rc1 were the most recent versions at the time of downloading the software. Protégé 4, intended for ontology development using OWL and not frames-based, was very new at the time and lacked support and training materials. A review of version histories (Stanford Center for Biomedical Informatics Research 2014b) for Protégé 3 and 4 shows a lack of stability in their versions, with many releases within a short time. Protégé 3.4.1 was the most stable recent frames-based version of Protégé available at the time and did not require the use of encoding to create an ontology.

Protégé 3.4.1 utilises an object-oriented way of thinking, where properties are subordinate to classes and are modelled in terms of A has Property P. More recent versions of Protégé do not use slots and are more abstract, with properties being modelled independently of classes, but applied to domains and ranges (eg, a Domain of medication, a range of Disease). While the newer versions allow more flexibility, Protégé 3.4.1 is easier to learn.

2.4.4 Evaluation of Ontologies

As of 2004, there was no common methodology for evaluating ontologies (Gomez-Perez 2004). Rogers (2006) reviewed literature on quality assurance for ontologies and found four broad criteria for evaluation: philosophical validity, compliance with meta-ontological commitments, 'content correctness',

and fitness for purpose. These criteria were not applied all at the same time to any one ontology reviewed by Rogers, repeating the conclusion of Gomez-Perez. Rogers commented that a perfect ontology might not be desirable, due to the increased likelihood of being overly complex. Five common evaluation criteria seemingly appropriate for biomedical ontologies, though also not necessarily consistently applied (Gruber 1993a) are:

1) Consistency
2) Completeness
3) Expandability
4) Conciseness
5) Sensitiveness

Consistency can be assessed by whether contradicting conclusions may be reached following the input of valid data. An ontology can be considered semantically complete (Gomez-Perez 1996) if:

> "(1) All that is supposed to be in the ontology is explicitly set out in it, or can be inferred using other definitions and axioms.
> (2) Each definition is complete. Semantic completeness of a definition refers to the degree to which the definitions in a user-independent ontology cover the equivalent concepts in the real world. We determine the completeness of a definition by figuring out:
> a) what information the definition defines or does not explicitly define about the world; and
> b) for all the information that is not explicitly defined, but required, we check if it can be inferred using other axioms and definitions. If it can be inferred, the definition is complete. Otherwise, it is incomplete."

An ontology is concise if it does not contain explicit redundancies and does not contain useless information. Expandability can be determined by the feasibility of adding new definitions to the ontology without interfering with the

other definitions. Sensitiveness refers to the impact of any changes to a definition after it has become linked to already-defined properties.

Noy and Tu (2003) describe the development of ‘competency questions’ as part of the ontology design process. Competency questions are intended to test whether the ontology fulfills its intended purpose. The types of questions that the ontology seeks to answer are shown in Chapter 5: Results: Evaluation (Section 5.6).

Statistical metrics identify baseline information for the ontology, enabling others to compare ontology characteristics. These metrics may also be used to identify potential modelling deficiencies and/or completeness of the ontology. A class with only one direct subclass may be a sign of a modelling problem or that the ontology is not complete. More than a dozen subclasses for a given class indicate that additional intermediate categories may be necessary (Noy and McGuiness [2002]). Recommended metrics to be calculated include (Musen, et al. 2012):

Number of classes

Number of individuals

Number of properties

Maximum depth

Maximum number of siblings

Classes with a single subclass

Classes with more than 25 subclasses

Classes with no definition

These metrics will be explained in Chapter 5, Results: Evaluation.

Noy et al. (2010) advocate for the use of social networking software, eg, BioPortal, in ontology development and implementation. BioPortal allows interested parties to comment on and reference components of ontologies. This supports the evaluation and maintenance of ontologies. Figure 2.2 shows how ontologies may be developed collaboratively through social networking and how this supports the evaluation process. Collaborative development,

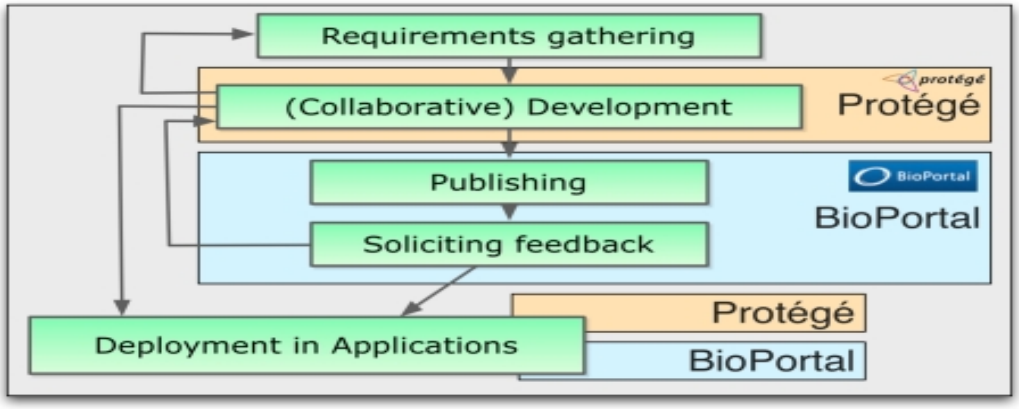

Figure 2.2 Ontology Lifecycle (Noy et al. 2010)

using Protégé, leads to a requirements gathering and deployment in applications, including BioPortal, a social networking website, which serves as a forum for publishing and soliciting feedback.

2.4.4.1 Justification of Selection of Evaluation Methodology

This ontology was a pilot, with unknown outcomes. Therefore a range of evaluation techniques were considered appropriate. Commonly used evaluation criteria, competency questions specific to the ontology, metrics and seeking opinions of others were used to evaluate the ontology.

Gruber's (1993a) five common

criteria of consistency, completeness, expandability, conciseness, and sensitiveness were chosen to evaluate this ontology, due to their widespread use as evaluation mechanisms for ontologies. Competency questions are important to assess whether the ontology achieved its intended purpose. Metrics recommended by the National Center for Biomedical Ontology (Musen et al.2012) were included as metrics, such as number of classes and subclasses can show that an ontology was warranted. An attempt was made to make the ontology publicly available for comment, as collaboration is recommended by Noy (et al. 2010) and suggestions from interested parties could be used to improve the ontology.

2.5 Clinical Practice Guidelines

2.5.1 Introduction and History

Clinical practice guidelines (CPGs), produced by professional societies to advise clinicians on the diagnoses and/or treatment of medical conditions, are becoming increasingly popular as a tool for improving the quality of health care. The United Kingdom's National Health Service requires Acute and Primary Care Trusts to report on compliance with clinical practice guidelines sanctioned by the National Institute for Health and Clinical Excellence (NICE). NICE's emphasis on cost-effectiveness has caused some drug companies to lower the cost of their drugs in the UK. Other countries, eager to seek the same influence over drug companies, are investigating NICE as a model for disseminating and monitoring the use of clinical practice guidelines. Insurance companies in the United States are experimenting with monitoring

the use of clinical practice guidelines to justify reimbursement of medical costs. Automated monitoring of compliance, via electronic health records, can be facilitated by the use of ontologies to assist with communication between electronic health records (EHRs) and reporting systems.

Various levels of expectations for health care quality have existed for hundreds of years, including medical education and licensing. The origin of the first clinical practice guideline is open to debate. Weisz (2007) points out that professional societies in the United States have had more influence over practice standards than those in many other countries due to multiple factors, including the lack of a centralised healthcare system. The profile of public health services increased in the nineteenth century, largely due to efforts to contain communicable diseases. The American Academy of Pediatrics' 1938 production of immunisation guidelines for children served as a model for further guideline development in the United States. CPGs began to proliferate in the 1970's, with global spread over the past two decades.

CPGs are not a panacea. It is important to remember that published guidelines may not include the most recent research and therefore be out of date. Efforts to address quality control issues in guideline selection and development have led to international collaboration. The Appraisal of Guidelines Research and Evaluation (AGREE) Instrument (AGREE Research Trust 2001) is now available in twenty languages. Although the AGREE Instrument has been endorsed by the World Health Organisation, other quality control mechanisms are available. The Guidelines International Network, a

community mostly based in European Countries, North America, and New Zealand, was founded in 2002 (Ollenschlager et al. 2004).

2.5.2 Computer-Interpretable Guidelines (CIGs)

2.5.2.1 Architecture

Guideline modelling can be approached in different ways. The knowledge-centric approach to computer-interpretable guidelines involves modelling guidelines so that they are compatible with related software, for example: search, display, and/or execution (Sonnenberg and Hagerty 2006). The document-centric approach views the original guideline format as the information base. This information is reformatted, for example into elements, and then tagged to work with related software. Some researchers are moving towards a hybrid approach of knowledge-centric and document-centric.

Arden Syntax is an example of the document-centric approach to CIGs. Arden Syntax is made up of medical logic modules (MLMs) (Hripcsak 1994). Evoking events, logic, action, and data mapping are the primary components of the MLMs. Clinical events evoke the logic, which is evaluated by the syntax using true/false criteria. Medical criteria and algorithms are used to specify the logic. The logic is actioned when components are assessed to be true. In order for the MLMs to work properly, the terms used in the institution-specific records (eg, information from local software records) must be mapped to the terms used in the MLM. Arden Syntax has been integrated into other CIG systems Wang et al. 2004).

Guideline modelling ontologies support automated compliance monitoring by formulating time-based task networks of clinical actions and decisions (Peleg 2011). These ontologies express concepts, abstractions and relationships, with tools for linking to electronic medical records.

Although there is no single process for developing CIGs, Figure 2.3 shows some of the steps likely to be included in a hybrid model for CIGs. The first step involves clinician development of sample clinical scenarios, including recommended actions. These may be informed by clinical guideline literature, which also informs the logic to be extracted from the scenarios. This logic is the second step. The third step involves the refinement of the logic into clinical concepts or terms. Steps four and five are interchangeable. One links the clinical concepts to detailed data model, which is informed by an abstraction of a medical record (eg, virtual medical record) and the other maps the clinical concepts to a standard terminology or reference terminology. The mapping in the latter of these two steps creates a vocabulary inventory. The final step is the computer-interpretable guideline itself, an amalgamation of the other steps.

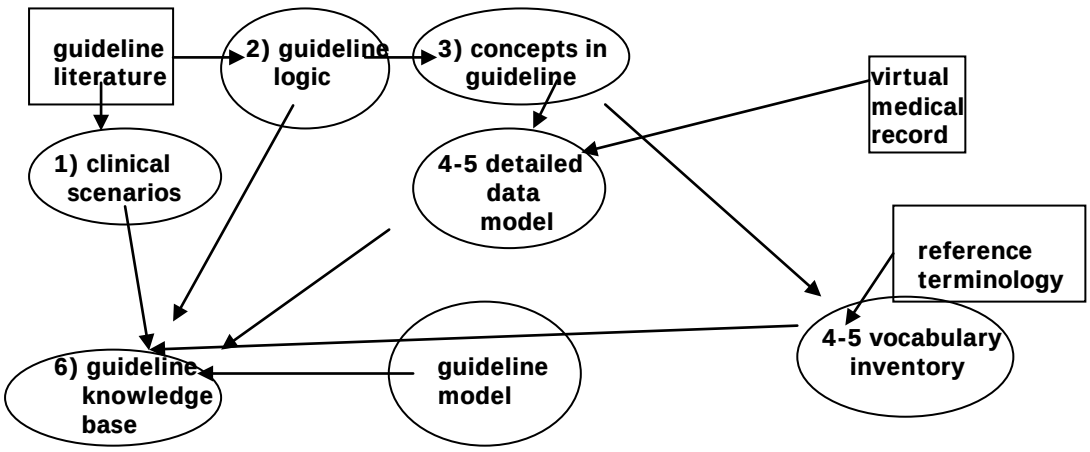

Figure 2.3. Steps and external relationships in a hybrid approach to modeling clinical practice guidelines for integration into workflow. The arrows represent information flow. Adapted from Tu et al. (2004).

2.5.2.2 Status

Recent review articles on computer-interpretable guidelines (Sonnenberg and Hagerty 2006, Peleg et al. 2003, Isern and Moreno 2008, Leong et al. 2007) cover different studies, have different objectives, and use different search strategies. Sonnenberg and Hagerty focussed on how guideline expression activities have influenced guideline implementation and support. Peleg and colleagues compared 8 components of the structure of 6 guideline expression models: Asbru, EON, GLIF, GUIDE, PRODIGY, and PRO*forma*. Isern and Moreno (2008) analysed eight guideline execution projects, some of which include models covered by Peleg. Peleg's KDOM mapper has potentially resolved EMR compatibility issues via SQL/GLEE translation (Peleg et al. 2008). Leong et al. (2007) have identified many free and open source tools for improving CIG systems. Anani et al. (2012) used graphical software (Visual Understanding Environment) as a step towards creating CIGs via openEHR, an open source electronic health records initiative.

Van Wyk and Van Wijk (2002) suggest that systems may need to interface with multiple guidelines in order to handle multiple co-morbidities. A review by Peleg et al. (2003) indicates that some ontologies can handle this issue, eg, GLIF, PROforma, and EON. However, Weng et al. (2010) note that ad hoc expression languages, such as EON, usually cannot handle formulas for quality indicators when the formula involves a relationship between two variables, raising questions about the methodologies used in the research cited by Peleg and Weng's research.

Isern and Moreno's (2008) review indicated that UMLS is the most popular controlled vocabulary tool used with guideline execution engines. It should be noted that UMLS is not a controlled vocabulary in and of itself, but a tool to map between selected controlled vocabularies that are integrated into UMLS. Sonnenberg and Hagerty (2006) believe that UMLS is not suited to temporal issues in guideline implementation. Shahar et al. (2006) have developed a 'Spock module' to handle temporal issues.

Many researchers appear to favour SNOMED for mapping CPGs to a clinical terminology. An advantage to SNOMED over most other controlled vocabularies is that it can be post-coordinated (Hrabak et al. 2007), therefore more flexible and able to handle complex concepts. Table 2.1 exemplifies the need for a flexible terminology by showing an attempt to map a NICE Hypertension CPG to the International Classification for Primary Care, with notes expressing the need for a more comprehensive clinical terminology. Cuggia et al. (2007) note that SNOMED is more suited to handling symptoms than ICD-10 and that DRGs may facilitate tracking care given by different departments. SNOMED can also map to CPT. (Elkin and Brown 2002). Bhensky et al. (2011) note the importance of identifying the version of clinical terminologies used.

Indicator	ICPC Proc	ICPC Diag 1	ICPC Diag 2	ICPC RFE 1	ICPC RFE 2	Notes
BP above 140/90 >1x	K31, if positive then K50	K86	K87			ICPC Diag 1 or 2
Lifestyle advice	K45	K85				
Urine test for protein	K35	K22				Need separate spec for protein
Blood test for cardiovascular risk	K34, if positive then K50	K22				Need separate spec for blood plasma glucose, electrolytes, creatinine,

Indicator	ICPC Proc	ICPC Diag 1	ICPC Diag 2	ICPC RFE 1	ICPC RFE 2	Notes
						serum total cholesterol and HDL cholesterol
12-lead electrocardiography	K42, if positive K50	K22				Need to specify persistent (min 2 visits) 160/100 or more OR persistent BP above 140/90 w/ 10-yr risk of CVD at 20%
Urine test for diabetes	T35	T89	T90			Need to specify drug type criteria if positive
Test for kidney disease	U34 &/or U35	U14	U14			ICPC 1 and/or 2
Test for Accelerated Hypertension	K39, if positive then K67	K87				Need to spec 180/110.
Papilloedema and/or retinal hemmorage		F01	F75?			Need to spec papilloedema, check non-contusion for F75
Assess for possible phaeochromocytoma	If positive then K67	K88	N01	K04	A09	Doublecheck coding allowance for 01 for diag
Annual review to discuss BP, lifestyle, meds	K31 & K45, possibly K50					

Table 2.1. NICE Guideline for Hypertension mapped to International Classification for Primary Care.

Kumar et al. (2003) have managed to reduce number of semantic types in UMLS from 100 to 9. This is intended to facilitate mapping to tasks within guidelines. Very little follow-up work has been done to indicate the success of Kumar's project.

CIG research is still evolving. It is worth noting that NICE (2013) still offers a spreadsheet mechanism for monitoring compliance with clinical practice guidelines. Figure 2.4 shows a screen shot from the compliance monitoring spreadsheet, using hypertension as an example. An ontology for clinical practice guides has the potential to incorporate or replace this spreadsheet, with guideline concepts and electronic health record components mapping to

a detailed data model, as previously shown in Figure 2.3.

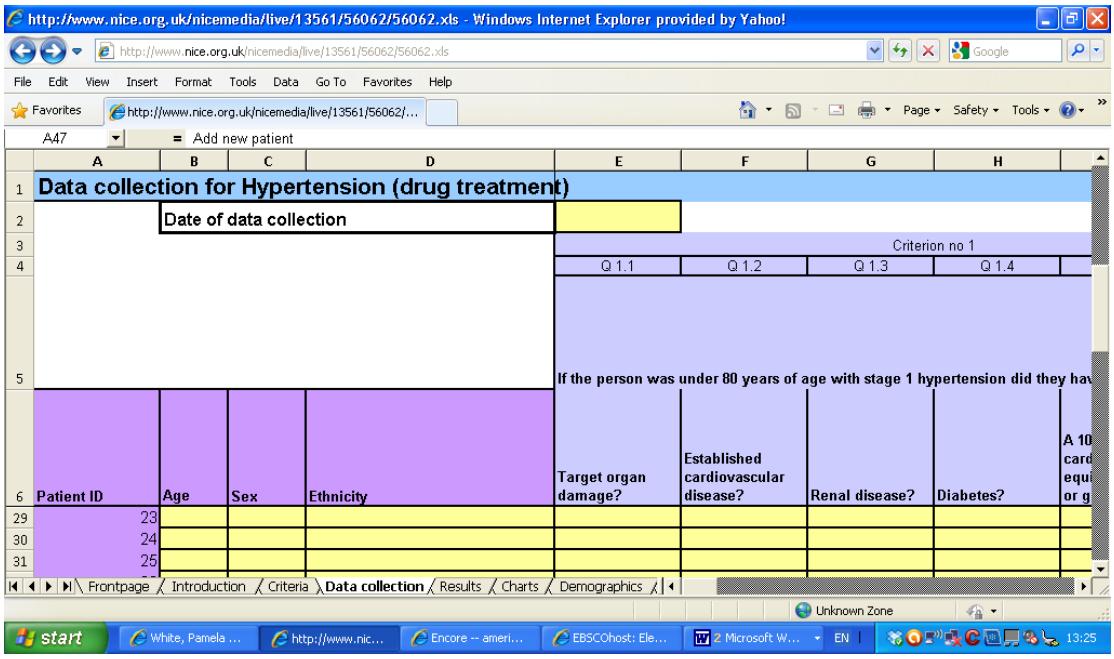

Figure 2.4 Screen shot from NICE (2013) Electronic Audit Tool, with hypertension as an example.

2.6 Quality Indicators

2.6.1 Definition and Assessment

Quality Indicators have been defined in Chapter 1 as measurable mechanisms for describing the structure, process or outcomes of care (Campbell et al. 2002, National Library of Medicine 1998). Donabedian (1966) explains that outcomes are frequently used as indicators of quality of health care. He warns that criteria for a successful outcome must be chosen carefully and considered in context. Other factors besides medical care may affect outcomes. Large amounts of time must pass before the outcome of some health care is known. The reason for success or failure is generally not identified in the recording of an outcome.

Process of health care, such as justification of diagnoses and selection of therapy, is another criteria often measured with quality indicators. These measurements are less stable, but often more directly associated with quality of health care than outcomes. Standards are often used to measure quality of process. A third means of measuring quality indicators is through health care structure. Structure can be assessed by examining the setting and equipment used in health care. A challenge with this method is that the relationship between structure and process is not always easy to define.

2.6.2 History and Development

While the US Joint Commission initially evaluated quality of health care through subjective peer review, they became more selective about evaluation criteria during the 1970's and joined the Continuous Quality Improvement movement during the 1980's (Luce et al. 1994). Mark Friedman's early twenty-first century work on Results Based Accountability has influenced quality monitoring in the UK as well as the US (Pugh [2009?]). There are numerous quality initiatives in the UK, including Payment By Results, Quality and Outcomes Framework, and the Quality, Innovation, Productivity and Prevention programme. These initiatives will be described in this section.

At the start of the twenty-first century, the NHS began to focus on audit of process and outcomes in healthcare monitoring (O'Connor and Neumann 2006), incorporating the concept of 'quality of life' into outcomes. Prices for 'Healthcare Resource Groups' or instances of similar treatment were initially priced on a national scale and reduced to elective care as of 2006. This

initiative was known as ‘Payment By Results’ and was still in use as of 2012. An overly bureaucratic organisation of the system, involving NHS Connecting for Health, the Department of Health and the Health and Social Care Information Centre, has led to crippling administrative costs and the temptation to reduce quality of care to compensate, in light of fixed tariffs. A 2011 report by the UK Audit Commission notes that Trusts’ classification of inpatient care versus outpatient care has placed an extra burden on management time that could be better spent on improving patient care (Audit Commission 2011).

A shift to implementing clinical care pathways and clinical practice guidelines is attempting to address some of the issues of the UK Payment By Results system (O’Connor and Neumann 2006). Trusts are currently not required to comply with the NHS Quality and Outcomes Framework (QOF), managed by the National Institute for Health and Clinical Excellence (BMA and NHS Employers 2012). However, the indicators, developed by NICE, are taken into consideration in contract negotiations between NHS Employers and the General Practitioners Committee and will be part of a more formal approach for NHS Commissioning in 2013 (Department of Health/NHS Finance and Operations 2011). The NHS uses QMAS (Quality Management and Analysis System) to record levels of compliance with QOF. The recording takes place either manually or through data extraction from electronic health records.

The business rules for recording compliance with QOF are primarily a formula:

> "Each dataset and business rule contains the information required to identify those patients who are eligible for inclusion on the disease register, indicator denominator and the indicator numerator. The denominator is made up of the patient population eligible for the care, as outlined in the indicator wording, and the numerator is the number of patients who have actually received the care." (NHS Employers 2012)

These rules are explained in more detail in the NHS Primary Care document, "Reading and Understanding the Dataset and Business Rules of the Quality and Outcomes Framework: A Guide" (Foskett-Tharby 2008).

Below is an example of a quality indicator developed by NICE, followed by two examples of AMA's 2012 Physician Quality Reporting System Quality Measures developed in the US.

Cardiovascular NICE indicator NM07 QOF ID: CHD14: (NICE 2010a) "The percentage of patients with a history of myocardial infarction from 1 April 2011 currently treated with an ACE inhibitor (or ARB if ACE intolerant), aspirin or an alternative anti-platelet therapy, beta-blocker and statin (unless a contraindication or side effects are recorded)"

1. Example of a quality indicator developed by NICE.

US 2012 Physician Quality Indicator: 0070: "**Heart Failure: Angiotensin-Converting Enzyme (ACE) Inhibitor or Angiotensin Receptor Blocker (ARB) Therapy for Left Ventricular Systolic Dysfunction (LVSD) -** Percentage of patients aged 18 years and older with a diagnosis of heart failure (HF) with a current or prior left ventricular ejection fraction (LVEF) < 40% who were prescribed ACE inhibitor or ARB therapy either within a 12 month period when seen in the outpatient setting or at each hospital discharge"

2. 1st example of AMA's 2012 Physician Quality Reporting System Quality Measures.

US 2012 Physician Quality Indicator 0081: "**Coronary Artery Disease (CAD): Beta-Blocker Therapy - Prior Myocardial Infarction (MI) or Left Ventricular Systolic Dysfunction (LVEF < 40%) -** Percentage of patients aged 18 years and older with a diagnosis of coronary artery disease seen within a 12 month period who also have prior MI OR a current or prior LVEF < 40% who were prescribed beta-blocker therapy."

3. 2nd example of AMA's 2012 Physician Quality Reporting System Quality Measures.

A counterpart to QOF is the Quality, Innovation, Productivity and Prevention programme (QIPP), sponsored by the Department of Health and overseen by NHS Improvement. QIPP emphasises workstreams and value for money and includes acute care as well as some primary care (NHS Information Centre 2009a).

The NHS Information Centre appears to be taking a more centralised role in providing access to NHS quality indicators (NHS Information Centre 2012a). In 2008, NHS information Centre and Department of Health surveyed NHS preferred quality indicators from a collated set (NHS Information Centre 2008). The resulting list includes over 200 indicators from diverse sources, such as the Quality and Outcomes Framework, Commissioning Data Sets, Hospital Episode Statistics, and various national audit efforts. The indicators are intended to support quality control efforts, NHS commissioning and patient choice (Department of Health 2012a). The indicators have a separate metadata system (NHS Information Centre 2009b) and lack the formal logic of an ontology. This set of indicators presents a useful opportunity to study NHS quality indicator features, with the intention of facilitating the gathering of data via computer for quality monitoring. While progress has recently been made (Department of Health 2012b) towards defining relationships between quality indicators, this has not been presented in an ontology context and there is further work to be done, including identification of inclusion and exclusion criteria, and establishing relationships between indicators from different sets.

2.6.3 Computer Interpretable Quality Indicators

Computer-based monitoring of quality indicators has traditionally been based on clinical coding. O'Toole et al. (2005) used electronic health records to monitor compliance with cardiovascular measurement sets. A data warehouse was created, using ICD-9 codes from EHRs. SQL queries were used to summarise clinical information, with analysis and report generation contracted to a commercial vendor. Weiner et al. (2005) found that EHR-based calculation of quality indicators had less false positives than manual chart review. A US initiative (Executive Office of the President 2010) to increase use of EHRs has led to improvements in compatibility of healthcare quality indicators with EHRs.

2.6.3.1 Data Sourcing

Data for quality indicators may be sourced from different service provision areas (Kelly 2012), including:

- Inpatient encounters
- Outpatient encounters
- Accident and Emergency encounters
- General Practice consultations
- Prescription events

While some of these data sources have been centralised in the UK, General Practice (GP) consultations have not been centralised. Data currently must be

submitted by individual practices, using MIQUEST or other services. However, some NHS quality indicators have been found to be too complex to be written as a MIQUEST query (Morris et al. 2004). A General Practice Extraction Service is under development to attempt to centralise GP data collection (Kelly 2012).

2.6.3.2 Use of Arden Syntax

Jenders (2008) tested Arden Syntax, which uses Medical Logic Modules (MLMs), to assess computer interpretability for a set of quality indicators ACOVE (Assessing Care of Vulnerable Elders). However, most MLMs, originally intended as automated single reminders, have been designed for the purpose of screening and prevention (Ohno-Machado et al. 1998). The results of Jenders' study showed promise, though sometimes showed only results of tests ordered, rather than the record that tests were ordered prior to showing results.

2.6.3.3 An Ontology for Public Health Indicators

Surján et al. (2004, 2006) attempted to create an ontology for public health quality indicators that would work across different sets of public health indicators. They found semantic limitations in the Resource Description Framework backend for Protégé's ontology editor and a need for integration of other domain ontologies, such as economic, social and environmental. Their model works better for some types of indicators than for others and is subject-specific to Public Health. While Public Health is a broad subject area,

quality indicators used to assess public health issues may be limited in scope. Wynden et al. (2010) have developed a Health Ontology Mapper that is intended to support integrated data repositories. The Mapper emphasises clinical terminologies and is not specific to quality indicators.

2.6.3.4 United States Quality Data Model

The US National Quality Forum recently released a Quality Data Model, intended to organise clinical concepts in such a way as to facilitate communications with electronic health records and clinical information systems (Sheber 2012). Their model takes a knowledge-centric approach to US quality measures, requiring quality indicator developers to conform to the framework, which is based on data supplied in EHRs. It involved a large-scale effort, with funding from the US government and input from representative electronic health records vendors and insurance companies (National Quality Forum 2009). The Forum's Health IT Expert Panel has also made recommendations as to which indicators should be used (National Quality Forum 2008), taking into consideration US priorities.

2.6.3.5 Challenges for Computer-Interpretable Quality Indicators

The development and implementation of computer interpretable quality indicators is still evolving (Thompson et al. 2012, Velamuri 2010, Moriarty et al. 2010). Issues with accuracy of electronic health records present a considerable challenge. The US Department of Health and Human Services (2012) has questioned the accuracy of hospitals' and clinics' self-reported

quality-monitoring data for the Centers for Medicare and Medicaid Services. Roth et al. (2009) rated accessibility of data in electronic health records for over 400 healthcare quality indicators. They identified the following challenges affecting automated health care quality indicator data extraction:

- Temporal issues, such as retaining outdated data,
- Duplicate data in multiple formats (eg, clinical coding vs free text),
- Vague documentation of patient education,
- Inaccurate medication lists,
- Incomplete and outdated diagnoses,
- Incomplete documentation in general (eg, blank data fields),
- Inconsistent use of ‘Chief Complaint’ (suggests that automated quality monitoring may be more suitable for chronic conditions, which are easier to identify), and
- Variation in EHR flexibility.

Application of computer-interpretable quality indicators can be hampered by lack of available data in electronic health records (Roth et al. 2009). Inclusion criteria had to be simplified in Jenders’ application of Arden Syntax to quality indicators, due to lack of corresponding EHR data. The use of queries containing exclusion criteria raised the number of false positives in a study conducted by Baker et al. (2007). To address this issue, Persell et al. (2010) have suggested the inclusion of exceptions to quality indicators in the recording of normal clinical workflow. Persell’s (et al. 2010) solution focuses

on enabling EHRs to better supply data that may be related to exclusion criteria. An ontology for quality indicators that specifies inclusion and exclusion criteria will facilitate computerised recording of quality indicator data by supplying indicator elements that may be useful to query writers and others involved in quality monitoring, as well as developers of electronic health records. These elements will need to be available in electronic health records. The ontology can highlight information that is either vital to include in health records or warning indicator developers that indicators need to be worded in such a way that facilitates data extraction. This document-centric approach, described (Sonnenberg and Hagerty 2006) as using the original clinical guideline format as the information base for computerisation, applied to quality indicators in this case, is useful in that it does not require EHR compatibility. It is instead intended as a stage toward EHR compatibility.

2.7 Summary

This chapter has reviewed literature on the concept of health care quality, clinical practice guidelines and quality indicators, with respect to computer interpretability and underscored the need for the research proposed for this thesis. While much progress had been made regarding the development of ontologies for clinical practice guidelines, efforts to develop ontologies for health care quality indicators are in early stages. Apart from the US National Quality Forum, (2008, 2009, Sheber 2012), very little work appears in the literature showing that the limitations of reliance on formulas to calculate quality indicators have been addressed. These limitations include:

1) Inadequate translation (Morris et al. 2004),

2) Increased false positives for exclusion criteria (Baker et al. 2007),
3) Discouraging the addition of new criteria to quality indicators due to the need to rewrite formulas (Mabotuwana and Warren 2010),
4) Missing clinical detail (Persell et al. 2010)
5) Inadequacy of relying on clinical coding (Benin et al. 2011).

Identification of levels of indicator relationships can serve as a step towards repackaging formulas into reusable components, making it easier to tailor and revise queries.

Some research described in this chapter (Surján 2004, 2006, Jenders 2008) has been specific to a particular area of healthcare, inviting exploration of attributes of a diverse set of quality indicators. This same research towards the development of computer-interpretable quality indicators (Surján 2004, 2006, Jenders 2008) has shown a need to improve specification of inclusion and exclusion criteria, along with categorisation beyond screening and prevention. Jenders' work with Arden Syntax (2008), appears limited in that Arden Syntax is most suited for the purpose of screening and prevention, while a large set of quality indicators may cover many more areas. It will be useful to apply the same Institute of Medicine categories used to describe this limitation of Arden Syntax (Ohno-Machado et al. 1998) to help justify the need for a separate ontology.

Chan et al. (2010) note a need for research into attributes of quality indicators to support electronic health record compatibility. The National Quality Forum (2012a) has acknowledged that their selection of quality indicators is heavily

dependent on the ability of EHRs to supply data. Jenders' use of Arden Syntax was also dependent on the ability of EHRs to supply data, as lack of data interfered with the development of queries for inclusion and exclusion criteria. Parsons et al. (2012) state that more studies are needed to specify which measures are best calculated using claims or administrative data or a combination of data sources. A smaller scale research project than that of the US could be used to inform similar projects in countries with less resources and different levels of EHR implementation than the US. An ontology that is more flexible than the US framework will allow developers of indicators and indicator sets to work at a pace that suits local, regional or national priorities, resources and staffing. The next chapter will describe the method chosen for this research.

Chapter 3 Methodology

3.1 Introduction

This chapter will explain the method chosen for this research and how the research was produced. The aim of the project was to investigate whether the conceptualisation stage of ontology development for a large set of health care quality indicators can facilitate flexible specification of inclusion criteria, along with specification beyond screening and prevention and identification of levels of indicator relationships. Ontology development has been described as an iterative process and is necessarily exploratory when the domain contains uncertainties. (Sachs 2006). A modified version of an evolving prototype methodology, Methontology, was chosen for this project, as one of several methods for creating an ontology.

The nine components of Methontology are: specification, knowledge acquisition, conceptualisation, formalisation, integration, implementation, documentation, evaluation and maintenance. **Specification** involves explaining the intended use of the ontology, along with the intended audience, and scope of terms to be represented. **Knowledge Acquisition** takes place during the specification process and may continue during other processes. Knowledge Acquisition often involves literature reviews and interviews. **Conceptualisation** is the informal representation of domain terms in the form of concepts, instances, verbs, relations, and properties. **Formalisation** uses frames-oriented or description logic systems to model the ontology. **Integration** attempts to address a common standard for ontologies, by incorporating definitions from other ontologies. **Implementation** occurs when

the ontology is translated into a formal language. **Evaluation** involves assessing the ontology for completeness, consistency and redundancy. **Documentation** entails the selection and organisation of documents produced during the entire process.

Maintenance and implementation are not part of this development process, as this is a pilot ontology. Application of the other categories will be described in the chapter. Consistency, completeness, expandability, conciseness and sensitiveness are among the criteria used to evaluate the ontology.

3.2 Application of Methontology

3.2.1 Specification and Knowledge Acquisition

Table 4.1 in Chapter 4 summarises the **Specification** for the proposed ontology. The ontology is intended to diminish workload for staff involved in quality monitoring by reducing duplication of effort required to calculate data for NHS healthcare quality indicators. The **Knowledge Acquisition** element, interpreted as acquiring knowledge relevant to development of the proposed ontology, is covered in Chapter 2, Literature Review, particularly 2.6.3.5, Challenges for Computer-interpretable Quality Indicators, Ontology Development Platforms and the Quality Indicator sections 2.4.3.5 and 2.6 and in 2.4.4, Evaluation of Ontologies. Interviews, although sometimes used during the Knowledge Acquistion process in Methontology, can be vulnerable to bias and interpretation difficulties on the part of the interviewee. Interviews

were therefore excluded from the Knowledge Acquisition process for the development of this ontology. Interviews would be worth considering for future development of this ontology.

3.2.2 Integration and Documentation

The first modification to Methontology was due to exploratory work with an already developed ontology, GLIF (Guideline Interchange Format) (Peleg et al. 2004a), to ascertain whether a new ontology was indeed warranted. This modification can also be considered as part of an attempt to **integrate** other ontologies. GLIF was developed, in part to resolve software compatibility issues with Arden Syntax (Jenders 2008, Peleg et al. 2001).

The following paragraphs describe the attempt to encode an endocrine indicator using GLIF, with encoding issues noted:

The indicator selected for encoding was Endocrine, etc. Indicator (NICE 2010b) NM14 QOF ID: DM26, which states:

> "The percentage of patients with diabetes in whom the last IFCC-HbA1c is 59 mmol/mol (equivalent to HbA1c of 7.5% in DCCT values) or less (or equivalent test/reference range depending on local laboratory) in the preceding 15 months"

The indicator was identified by NICE as follows:

NM14 QOF ID: DM26
BMA/NHS Employers

An attempt to encode the indicator, using GLIF, was documented as:

Has parts

Patient State = Diabetes
[The percentage of] patients with diabetes = Decision Step

Branches to: in whom the last IFCC-HbA1c is 59 mmol/mol (equivalent to HbA1c of 7.5% in DCCT values) or less (Decision)
Which is Synchronized with: (or equivalent test/reference range depending on local laboratory) (Decision)
in the preceding 15 months = Decision step

Limited metadata and a lack of depth show this indicator is not compatible with GLIF. Individual authors for quality indicators are not specifically identified on the NICE website, although a referring link is given to National QOF Guidance, and a code, rather than mneumonic name is given. This limits the detail anticipated by the GLIF encoding methodology. Additionally, the above may conceivably simply be entered as eligibility criteria for a complex guideline. GLIF is intended to accommodate complex guidelines, with the ability to model events, logical criteria, and actions (Peleg 2001). Clinical practice guidelines are more complex than quality indicators (Walter 2004). GLIF was therefore ruled out as inappropriate.

The attempt to encode a quality indicator with GLIF contributed to the intention that the newly developed ontology would emphasise eligibility criteria. The goal of emphasising eligibility criteria was informed by Benin et al (2011) and modified to emphasise defining the target population, using inclusion/exclusion criteria. Benin et al. (2011) suggest separating the target population from the monitored outcome during the ontology development process. A modified version of Benin's method follows:

Indicator Target Population (denominator)

1) Create ontology that establishes target population.
2) Determine if target population can also be identified using SNOMED-based or other administrative data source.

3) If Yes, continue with plan. If No, explore alternative mechanisms before continuing with plan.

4) Identify target population using SNOMED-based or other administrative (eg, READ) or alternative data source.

5) Create Venn diagram of the target populations identified.

Indicator Outcome (numerator)

1) Revise ontology to establish indicator outcome among those patients in the target population

Although Benin's principles cannot be tested for this ontology, due to lack of access to electronic health records, the principles have been kept in mind during the ontology development.

The **Integration**, or the incorporation of definitions from other ontologies, has also been addressed in the ontology itself, by incorporating clinical codes and their corresponding terms from the Unified Medical Language System.

Documentation is a focus of this chapter and also Tables 4.1, Ontology Specification, 4.2, Glossary of Terms, and 5.1, Number of Indicators by Institute of Medicine Purpose for Clinical Guidelines, and Appendices 2-8.

Maintenance and **Implementation** are not part of this development process, as this is a pilot ontology. There is potential for further development and maintenance.

3.2.3 Conceptualisation

Conceptual knowledge can be defined as "a combination of atomic units of information and meaningful relationships between those units" (McCormick 1997). The Conceptualisation stage in Methontology involves the informal representation of domain terms in the form of concepts, instances, relations, and properties. Categorical sorting, repertory grid analysis and formal concept analysis are conceptualisation techniques selected for the development of this ontology. These techniques were chosen from Payne's et al. (2007) literature review on conceptual knowledge acquisition.

3.2.3.1 Conceptualisation Techniques Considered

Payne et al. (2007) reviewed literature on conceptual knowledge acquisition, describing a taxonomy of knowledge acquisiton techniques with three main categories: Knowledge Unit Elicitation, Knowledge Relationship Elicitation and Combined Elicitation. Knowledge Unit Elicitation is very similar to the Knowledge Acquisition stage in Methontology, involving interviewing and/or observations. Knowledge Relationship Elicitation is similar to the Conceptualisation stage in Methontology, involving categorical sorting, repertory grid analysis and/or formal concept analysis. Combined Elicitation involves protocol analysis, discourse analysis, sub-language analysis, laddering and/or group techniques.

Categorical sorting is useful for identifying relationships between units of information. Categories are an important component of this ontology and

similar to the concept of class, mentioned in repertory grid analysis. Repertory grid analysis involves setting up a table or grid, with units of information organised by class. Classes of information units are created using the ontology development software, Protégé 3.4.1, chosen for this project. Formal concept analysis emphasises relationships between units of information, though in a more complex way, with entities and entity-attribute pairings. Formal concept analysis has been particularly popular with ontology developers (Cimiano et al. 2004, Payne et al. 2007).

Protocol and discourse analyses are suited to problem-solving or reasoning and analysis of text or recorded speech. While some analysis of the text of the metadata for quality indicators is applied during the development of this ontology, the analysis is used to highlight issues for ontology development, rather than integration into the ontology itself. Sub-language analysis is also text-based and often involves natural language processing, which is not part of this thesis, but may be worth considering in future quality indicator ontology research.

Conceptual laddering is relational in nature, utilising tree structures and hierarchical relationships. Laddering could be useful to this ontology, though could be unwieldy to apply to a large set of quality indicators. Group techniques emphasise consensus and can be subject to bias if the power distribution between the parties involved is disparate. Group techniques would be appropriate to consider for formal implementation of this ontology.

3.2.3.2 Conceptualisation Applied to this Ontology

Much of the conceptualisation for this ontology is described in Chapter 4, Results: Methontology Components and the Ontology. Specifically, 4.2, Conceptualisation, includes subsections 4.2.1, Glossary of Terms, 4.2.2.1, Indicators Categorised by Quality Indicator Dimensions and Next Stage Review Pathways, 4.2.3, Indicators listed by Institute of Medicine Purpose, with Related Indicators, 4.2.4, Inclusion and Exclusion Criteria, 4.4.3 Form Editing and Issues Log, 4.4.1.

3.2.3.2.1 Appendix 2, the NHS HSCIC's Metadata Headings list

Section 4.2.1, Glossary of Terms, explains how the Glossary was created, with reference to the NHS HSCIC's Metadata Headings list (Appendix 2) and its use as inspiration for the Glossary of Terms, the starting point for conceptualisation of the ontology. Definitions for the NHS HSCIC's Metadata Headings list are available from the NHS Information Centre's (2009b) Indicator Metadata Library Guide, along with clarifying information, such as purpose and examples.

3.2.3.2.2 Appendix 3, Quality Indicator Dimensions and Next Stage Review Pathway

Appendix 3 (Quality Indicator Dimensions and Next Stage Review Pathways), explained in 4.2.2.1, Indicators Categorised by Quality Indicator Dimensions and Next Stage Review Pathways, as part of the conceptualisation results, shows quality indicators grouped by dimension, clinical pathway, and source.

This information was taken from the metadata supplied by the NHS HSCIC for each indicator, with the source sometimes subjectively imputed by the researcher. This was due to variability in information supplied by the NHS HSCIC. Grouping indicators by dimension and clinical pathway shows a different conceptualisation for the indicators than the one provided by the NHS HSCIC because it shows a repertory grid analysis of the indicators, with dimension and clinical pathway applied as categories or classes.

A Snapshot rule was created to address different status levels of the indicators when their metadata was entered into Appendix 3. If an indicator had a status of ***Dropped*** at the time of recording metadata into Appendix 3, the instance was not entered into the ontology. If an indicator had a status of ***Dropped*** after it was recorded into Appendix 3, the indicator was entered as an instance into the ontology. If an indicator had a status of ***Replaced by***, at the time of recording into Appendix 3, the indicator was not entered into the ontology. If an indicator had a status of ***Replaced by*** after recording the indicator into Appendix 3, it was entered into the ontology.

3.2.3.2.3 Appendix 4, Indicators by US Institute of Medicine Purpose, with Related Indicators

Appendix 4 categorises the indicators by US Institute of Medicine purpose (Field and Lohr 1992), along with related indicators and is explained in 4.2.3, Indicators listed by Institute of Medicine Purpose, with Related Indicators. This categorisation was subjectively determined by the researcher, using examples

given by the IoM for guidance to assign purpose(s). It was not based on information supplied by the NHS HSCIC.

A secondary purpose of Appendix 4 was to list broader, narrower and same level related indicators for each indicator indexed. This was accomplished by analysing words in the NHS HSCIC metadata for Definition and Title (renamed ‘Statement’ in this ontology) for each indicator. For example, it was determined that the indicator, CV34 (Statement = “ST-elevation myocardial infarction (STEMI) patients who received thrombolytic treatment within 60 minutes of call”) is broader than indicator CV36 (Statement = “ST-elevation myocardial infarction (STEMI) patients who received thrombolytic treatment within 60 minutes of call, who [also] received primary angioplasty within 120 minutes of call (call to balloon time)”) because CV36 includes the criteria specified for CV34, but includes additional criteria. Thus, CV 34 is broader than CV 36.

3.2.3.2.4 Appendix 5, Inclusion and Exclusion Criteria

Appendix 5, explained in 4.2.4, Inclusion and Exclusion Criteria, lists layers of inclusion and exclusion criteria for each indicator. Inclusion criteria were taken NHS HSCIC metadata for Definition and Title (renamed ‘Statement’ in this ontology). Exclusion criteria are taken from any field that mentions “excludes” or a similar word or phrase. Number of layers of criteria, including identification of phrases of relevant text, was subjectively determined by the researcher. The NHS HSCIC sometimes identified a numerator and

denominator in their metadata. This information, when made available, was taken into consideration by the researcher.

3.2.3.2.5 Appendix 6, Issues Log

Appendix 6 is an Issues Log, established by the researcher to track issues encountered during the ontology development process. Column headings include Date, Issue, Date Resolved, and How. Resolution of the issue is recorded in the 'How' column.

3.2.4 Formalisation

Formalisation has been addressed through the use of the Protégé platform for ontology development. Selection of the Protégé platform was influenced by the availability of instructional materials and its suitability for people new to ontology development. Selection of the platform for ontology development is explained in section 2.4.3.5.1, Justification of Selection of Protégé 3.4.1. Formalisation is also discussed in Chapter 4, section 4.4, Formalisation: The Ontology. Formalisation included the creation of classes and subclasses, along with slots and subslots (properties) of the classes and subclasses.

When creating a new ontology in Protégé 3.4.1, the default screen has a Class Browser on the left side of the screen and a Class Editor on the right side. The researcher added new classes by clicking on the sun icon in the Class Browser and renaming the classes in the Class Editor, with definitions copied from the Glossary of Terms entered into the Documentation box in the

Class Editor. Constraints were kept to a minimum to keep the ontology flexible. Roles for each class were specified as concrete if they could be represented with instances. Roles were specified as abstract if they could not be represented with direct instances.

Slots were added for each class by clicking on the sun icon in the Template Slots section of the Class Editor or by clicking on the Slots tab towards the top of the screen, followed by the sun icon in the Slot Browser and using the Slot Editor to change the default name for each slot. Cardinality for each slot was specified as Multiple or Single, depending on whether more than one value could be entered for that slot.

The Forms tab allowed the researcher to organise the slots in a logical order. By selecting a Display Slot of Unique Identifier for the Indicators class, the researcher enabled search results for queries of the finished ontology (using the Queries tab toward the top of the screen) to identify individual indicators.

3.2.4.2.6 Appendix 7, Classes and Subclasses

Appendix 7, explained in 4.4.1, Classes and Subclasses, shows the classes and subclasses of the ontology, along with their definitions. The classes and subclasses were identified from the initial Glossary of Terms, created at the beginning of the conceptualisation process for this ontology. Most of the definitions were taken from the NHS Information Centre for Health and Social Care's Metadata Guide (2009b), from Darzi's Next Stage Review (2008), by the US Medical Institute Purposes for Guidelines (Field and Lohr 1992).

Definitions for the Indicator class and Formula subclass, Inclusion/Exclusion Criteria, were created by the researcher.

3.2.4.2.7 Appendix 8, Slots and Subslots

Appendix 8, explained in 4.4.2, Slots and Subslots, shows the properties identified for the classes and subclasses. The slots and subslots for the Dimensions classes were taken from Darzi's Next Stage Review (2008). The initial Glossary of Terms, created at the beginning of the conceptualisation process for this ontology and categories identified in the tables used to conceptualise the ontology were used to identify the other slots. Section 4.2.1, Glossary of Terms, shows which headings in the Glossary of Terms were sourced or modified from the NHS HSCIC and which headings were created by the researcher. Definitions for the slots were created by the researcher.

3.2.5 Instances

The process for populating Protégé with instances of the indicators involved copying and pasting metadata from the tables grouping related indicators together and listing inclusion and exclusion criteria (Appendices 3-5). The metadata was recorded into the slots for the class of Indicators. The Instance Editor was accessed by highlighting the word 'Indicator' in the Class Browser on the left side of the screen and clicking on the Instances tab towards the top of the screen. This resulted in a display of slots previously created by the researcher for the class of Indicators.

Instances were not recorded for the other classes in the ontology, due to time constraints and the priority of making related components of indicators searchable. Metadata was not recorded for slots with no values and consistently not recorded for the Version slot, as information regarding indicator version was rarely available and deemed low priority for a pilot ontology.

3.3 Summary

This chapter has described the methodology used for this research. Methontology was identified as the preferred method, along with Protégé 3.4.1 as the preferred development platform. The project specification was introduced, including the intended use, intended audience, and scope of terms. Application of Methontology components during this project was explained. The creation of Appendices 3-8 was described, with Appendix 2 noted as inspiration for the Glossary of Terms. The next two chapters review the results of this research.

Chapter 4 - Results: Methontology Components and the Ontology

This chapter presents the results of the development of the ontology, using Methontology. The results of the specification, knowledge acquisition, conceptualisation, formalisation, integration and documentation components of Methontology, used to develop the ontology, are summarised, with the evaluation component described in Chapter 5. The aim of the project was to develop a pilot ontology that specifies inclusion and exclusion criteria, along with relationships between quality indicators and categorisation of indicators by Institute of Medicine (Field and Lohr 1992) purpose.

Table 4.1 shows the Specification for the ontology. Developed as part of the Conceptualisation process, a Glossary of Terms defines the initial metadata for individual indicators (Table 4.2). Table 4.3, created by the NHS Information Centre (2009a) and included to show the context for developing Appendix 3 (Quality Indicator Dimensions and Next Stage Review Pathways), shows numbers of indicators for pathways and associated dimensions. Appendix 3 shows quality indicator listed by dimension, clinical pathway, and source. Appendix 4 categorises the indicators by type and purpose, along with related indicators. Appendix 5 lists layers of inclusion and exclusion criteria for each indicator. Formalisation, the creation of the ontology itself, is described in Section 4.4. The resulting ontology, made available in Appendix 9, is a mechanism for finding common components of healthcare quality indicators from different sources.

4.1 Specification and Knowledge Acquisition

The Specification, shown in Table 4.1, notes that the ontology is intended to diminish workload for staff involved in quality-monitoring by reducing duplication of effort required to calculate data for NHS healthcare quality indicators. The intended audience includes: Clinical auditing communities, quality indicator developers, organisers of quality indicator sets and providers of access to quality indicator sets. The scope of terms includes: Public Health Indicators, GP Practice indicators, Commissioning indicators, Acute care indicators, Inclusion and exclusion criteria, Numbers and percentages, and Physical and mental symptoms.

Intended use	Replacement of tailored queries for quality indicators with searchable, reusable components
Intended audience	Clinical auditing communities, Quality indicator developers, Organisers of quality indicator sets, Providers of access to quality indicator sets
Scope of terms	Public Health Indicators, including those from the Compendium of Population Health Indicators and the Local Basket of Inequalities Indicators GP Practice indicators Commissioning indicators, including the NHS Outcomes Framework Acute care indicators, including the Summary Hospital-level Mortality Indicator Inclusion and exclusion criteria Numbers and percentages, including age, dates, dosages and test results Physical and mental symptoms

Table 4.1. Ontology Specification

The **Knowledge Acquisition** element, interpreted as acquiring knowledge relevant to development of the proposed ontology, is covered in the Chapter 2, Literature Review, particularly 2.4.3.5, Ontology Development Platforms,

and the Computer-interpretable Quality Indicator section 2.6.3 and Summary 2.7 and in 2.4.4, Evaluation of Ontologies in Chapter 2. The Knowledge Acquisition element showed that computer-interpretable quality indicators are in very early stages, with interoperability a key concern.

4.2 Conceptualisation

Conceptualisation involved the informal representation of domain terms in the form of concepts, instances, relations, and properties. Following the development of a glossary of terms, the conceptualisation techniques of categorical sorting and repertory grid analysis were used to analyse relationships between classes of information. The categorical sorting and grid analysis took the form of tables, created in Microsoft Word.

The categories of Clinical Pathway and Quality Dimension, along with Dimension and related sets chosen were based on Lord Darzi's Next Stage Review (Darzi 2008), a vision for the NHS, collated from ten Strategic Health Authorities. The categories for Purpose were chosen from the [US} Institute of Medicine's (Field and Lohr 1992) purposes listed for clinical practice guidelines. These were applied to the quality indicators selected for this project due to Ohno-Machado's (et al. 1998) comment that Arden Syntax is best suited for Prevention and Screening guidelines. Arden Syntax was originally intended to facilitate computer-interpretable guidelines and was applied to quality indicators in 2008 (Jenders 2008). This is further explained in 4.2.3, Indicators listed by Institute of Medicine Type and Purpose Categories with Related Indicators, and discussed in 6.2.2.2, Conceptualisation: Categorisation of Indicators by Purpose.

4.2.1 Glossary of Terms

The Methontology approach recommends development of a Glossary of Terms (Table 4.2). Appendix 2 shows the NHS Health and Social Care Information Centre (NHS HSCIC) Metadata Headings list, used to inspire the Glossary of Terms and the starting point for conceptualisation. As the list of indicators was supplied by the NHS HSCIC, it was deemed appropriate to consider the metadata headings used to describe the indicators by the NHS HSCIC for the glossary of terms. Definitions for the NHS HSCIC's Metadata Headings list are available from the NHS Information Centre. (2009b) Indicator Metadata Library Guide, along with clarifying information such as purpose and examples.

The headings selected from the NHS HSCIC were: Library Reference Number/Identifier (renamed 'Unique Identifier' as this metadata should not be duplicated), Source (renamed 'Reference' as 'Source' is ambiguous), Title (renamed 'Statement' as Titles are generally not duplicated in other types of metadata and in library catalogues), Calculation/Methodology/ Formula (renamed 'Formula' and used in a narrower context), URL (this is a modification of the NHS HSCIC's 'Accessibility' heading, which refers to potentially unlimited published information relating to the indicator), Publisher, Version (renamed 'Version History'), Other Related PI's (renamed Relations) and Notes (with a slightly different definition).

The following headings were added to supplement those chosen from the NHS HSCIC list: Creator, Access Point, Clinical Terminology Code, Dimension, Next Stage Review Pathway and Purpose. Although the NHS HSCIC had a 'Creator/Producer' heading, this referred to the party responsible for providing the outcome data for the indicator, rather than the creator of the indicator formula, methodology or intent. Access Point was added, due to the intended audience including clinical auditing communities and providers of access to indicator data sets. Clinical Terminology Code was added because clinical codes can assist with sourcing data for indicator outcomes. Dimension, Next Stage Review Pathway and Purpose were added to assist with categorical sorting and grid analysis and to support the objectives of this research.

Term	**Explanation**
Unique Identifier	Unambiguous reference number or string of letters and/or numbers
Reference	The source from which the indicator has been derived; normally the dataset applied [Referred to as 'Source' in IC Metadata Guide]
Statement	A sentence or paragraph clearly describing what is being measured [Referred to as 'Title' in NHS IC Metadata Guide]
Formula	Formula for determining indicator data result
Creator	Developer of the indicator content [NHS IC definition differs in that it refers to the party responsible for creating the data requested by the indicator]
Publisher	Party or parties responsible for making indicator available
Version History	Record of revisions to the indicator
Access Point	Location(s) of results
Relations	Other indicators which may need to be considered in conjunction with this indicator and vice versa
Clinical Terminology Code	The clinical term or terms used to source data to calculate the indicator, along with the corresponding codes
URL	URL with the most detail about methodology
Dimension	Three dimensions, identified from a collated vision from ten NHS Strategic Health Authorities (Darzi 2008): 1) Effectiveness 2) Safety 3) Patient Experience
Next Stage Review	Eight priority clinical areas, also known as pathways, identified

Pathway	in a collated vision from ten NHS Strategic Health Authorities (Darzi 2008) : 1) staying healthy 2) maternity and newborn care 3) children and young people 4) mental health 5) long-term conditions 6) planned care 7) acute care 8) end of life care
Purpose	The Institute of Medicine (Field and Lohr 1992) purposes [intended for clinical practice guidelines, but applied here to quality indicators]: Screening and prevention Diagnosis and prediagnosis management of patients Indications for use of surgical procedures Appropriate use of specific technologies and tests as part of clinical care Indicators for care of clinical conditions
Notes	Miscellaneous information to support the organisation and referencing of quality indicators.

Table 4.2. Glossary of Terms. The majority of the terms have been sourced or modified from the NHS Information Centre's Metadata Guide (NHS Information Centre 2009b). The original Metadata Guide list of terms appears in Appendix 2.

4.2.2 Quality Indicator Dimensions and Next Stage Review Pathways

In 2008, Professor the Lord Darzi of Denham KBE published a collated vision for the NHS from ten Strategic Health Authorities (Darzi 2008). The Strategic Health Authorities were asked to focus on eight clinical areas, also known as pathways. They include: Acute Care, Children's Health, End of Life Care, Learning Disabilities, Long Term Conditions, Maternity and Newborn, Mental Health, Other, Planned Care and Staying Healthy. Darzi identified three broad dimensions, Effectiveness, Safety and Experience, to categorise the eight clinical areas. The NHS Information Centre has indicated the Next Stage Review Pathway for each indicator in their 2009 list, along with which of the three dimensions identified in Lord Darzi's highly cited paper (2008) applies to

the indicator. Table 4.3, created by the NHS Information Centre (2009a), shows number of indicators in the each Next Stage Review Pathway and their related Dimensions. Although the indicators themselves are not identified in this table, it is a useful summary of the totals for the dimensions within each pathway.

Pathway	*Quality Dimension*		
	Safety	**Effectiveness**	**Experience**
Acute Care		18	
Children's Health		5	
End of Life Care		3	
Learning disabilities		1	
Long Term Conditions		45	1
Maternity and Newborn		3	
Mental Health	3	11	
Other		4	28
Planned Care	8	91	29
Staying Healthy		3	

Table 4.3. Numbers of Indicators for Pathways and Associated Dimensions. (NHS Information Centre 2009a).

4.2.2.1 Indicators Categorised by Quality Indicator Dimensions and Next Stage Review Pathways

Appendix 3 shows the indicators grouped by their respective Dimensions and Next Stage Review Pathways. While the NHS HSCIC listed the Next Stage Review (Darzi 2008) Dimension and Clinical Pathway for each indicator and created a table showing the number of indicators for each Dimension and Clinical Pathway, they did not create a table showing which indicators were assigned to each area and grouping these indicators together. Such a table is useful to the conceptualisation process because it shows how different indicators, including indicators from different sources, are related.

4.2.3 Indicators listed by Institute of Medicine Purpose, with Related Indicators

Appendix 4, Indicators listed by Institute of Medicine Type and Purpose Categories, with Related Indicators, is inspired by Ohno-Machado's (et al. 1998) comment that Arden Syntax is best suited for Prevention and Screening guidelines. The intention of Appendix 4 was to assess how many of the 2009 list of indicators fit into the category of Prevention and Screening and are therefore suited to expression in Arden Syntax. A secondary purpose was to list broader, narrower and same level related indicators for each indicator indexed. The Institute of Medicine purposes are described as follows:

> **Screening and prevention**: Eg, Vaccination for pregnant women who are planning international travel.
>
> **Diagnosis and prediagnosis management of patients**: Eg, Evaluation of chest pain in the emergency room.
>
> **Indications for use of surgical procedures**: Eg, Indications for carotid endarterectomy.
>
> **Appropriate use of specific technologies and tests as part of clinical care**: Eg, Use of autologous or donor blood for transfusions.
>
> **Guidelines [Indicators for the purposes of this research] for care of clinical conditions**: Eg, Management of patients following coronary-artery bypass graft. (Field and Lohr 1992)

4.2.4 Inclusion and Exclusion Criteria

Appendix 5 lists inclusion and exclusion criteria for each indicator, taken from the NHS Information Centre's Statement metadata. Boolean criteria are kept within the same level, unless they require additional, separate steps. Number of layers vs number of concepts can sometimes be an issue, particularly with respect to patient experience indicators.

Inclusion criteria are generally taken from the indicator Statement, for the sake of continuity and to keep excessive efforts required to pull formulaic detail from the metadata and from the referring links to a minimum. Exclusion criteria are taken from any field that mentions "excludes" or a similar word or phrase.

4.3 Integration and Documentation

The **Integration**, or the incorporation of definitions from other ontologies, has also been addressed in the ontology itself, by incorporating clinical codes and their corresponding terms from the Unified Medical Language System. Clinical Terminology Code is one of twenty-nine slots developed as part of the ontology (See 4.4.2, Slots and Subslots, and Appendix 8, Slots and Subslots). Because the attempt to apply GLIF, an ontology intended for computer-interpretable guidelines, to a quality indicator showed that GLIF was overly complex for that indicator, no definitions were incorporated from GLIF. Additionally, the definitions for the classes in GLIF did not appear compatible with the classes determined from the NHS Information Centre for Health and Social Care's Metadata Guide (2009b). The definitions ruled out from GLIF were:

The **Decision_Step** class represents decision points in the guideline. A hierarchy of decision classes provides the ability to represent different decision models.

The **Action_Step** class is used for modelling actions to be performed. Action steps contain tasks. Two distinct types of tasks can be modeled: medically oriented actions such as a recommendation for a particular course of treatment, and programming-oriented actions such as retrieving data from an electronic patient record. Nesting of steps, discussed in Section 8, allows recursive specification of actions and decision. In other words, through nested steps, one can specify details of high-level actions and decisions as subguidelines.

The **Branch_Step** and **Synchronization_Step** allow modelling of multiple simultaneous paths through the guideline.

Patient_State_Steps serve as entry points into the guideline as well as allow for labeling patient states (e.g., a state of taking one anti-hypertensive drug). (Peleg 2004b)

Documentation of each of the Methontology steps applied is a focus of much of this thesis, including selection and organisation of chapters, figures, tables and appendices. The following components of Methontology were not used for this research: Implementation and Maintenance. **Formalisation** will be described in the next section of this chapter. **Evaluation** will be described in Chapter 5.

4.4 Formalisation: The Ontology

The ontology was developed using Protégé 3.4.1 as a platform. Classes of Dimension, Next Stage Review Pathway, Indicator and Purpose were created, with Subclasses shown in Figure 4.1, as viewed via the publicly available National Center for Biomedical Ontologies website, (Musen et al. 2012). The ontology itself is on a CD attached to the end of this thesis. Appendix 9 explains how to access the ontology. The explanation also appears at the end of this chapter.

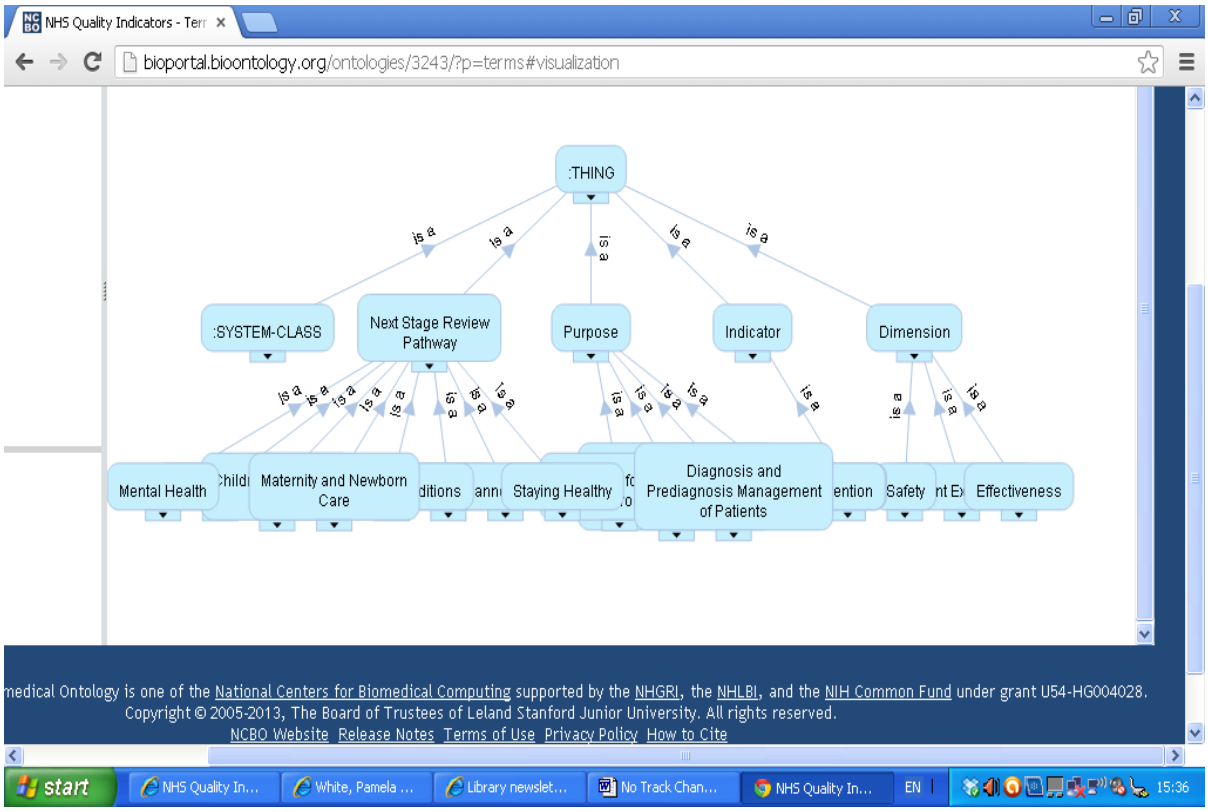

Figure 4.1. Ontology Classes and Subclasses.

4.4.1 Classes and Subclasses

The Classes and Subclasses, along with their definitions, are shown in Appendix 7. Definitions were inspired by the NHS Information Centre for Health and Social Care's Metadata Guide (2009b), from Darzi's Next Stage

Review (2008), by the US Medical Institute Purposes for Guidelines (Field and Lohr 1992) and by the Anglo-American cataloguing rules (American Library Association et al. 2012). Cataloguing, a technique for creating or improving access to information and principle focus of Library Science, can be applied to metadata regarding digital and non-digital information resources to facilitate organisation and access.

4.4.2 Slots and Subslots

Following creation of classes and subclasses, thirty slots (properties) and nine subslots were created and assigned to the classes and/or subclasses. The Indicators class was assigned twenty-nine slots. The Dimension subclass of Effectiveness was assigned four slots. The Dimension subclass of Patient Experience was assigned three slots. The Dimension subclass of Safety was assigned three slots. The slots, organised by their assigned class or subclass, are defined in Appendix 8.

4.4.3 Form Editing and Issues Log

Form editing was limited to the Indicators class, as the time required to enter instances of the Indicators led to the slots for the other classes receiving low priority. Figures 4.2 and 4.3 show two screen shots for the Indicators Form.

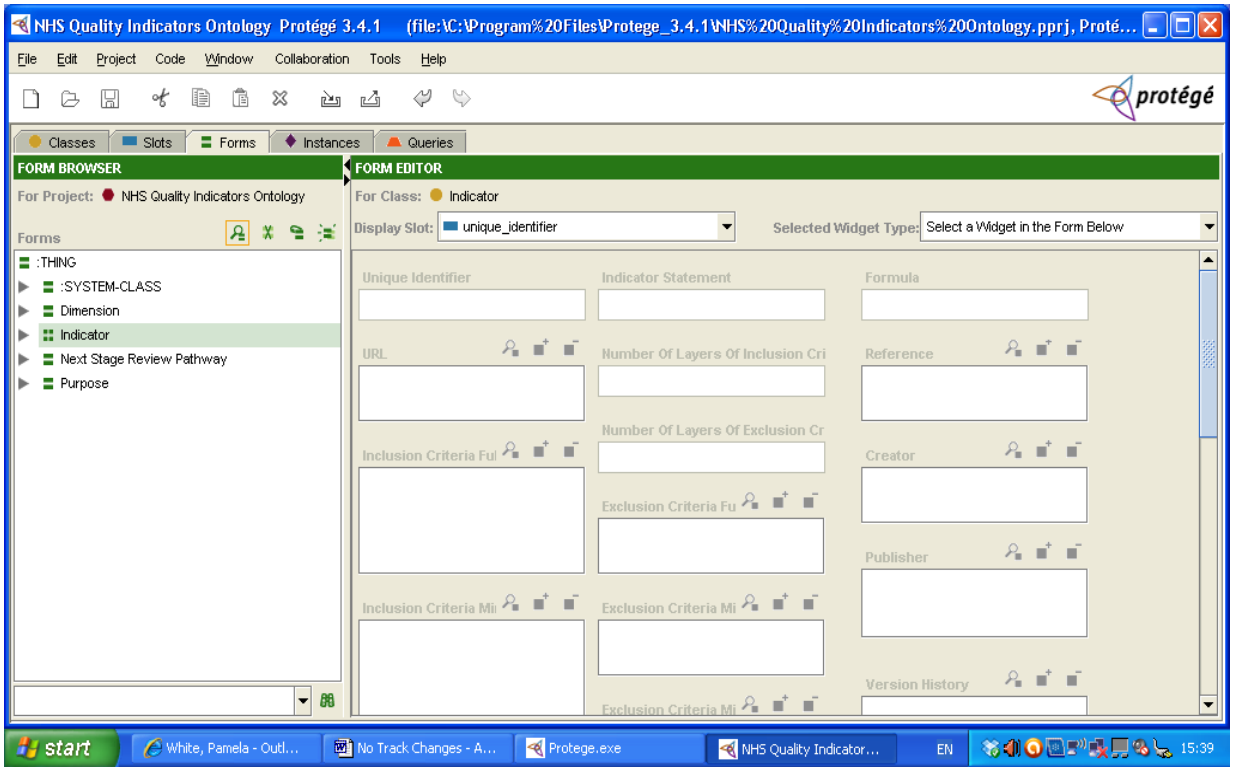

Figure 4.2. First part of the form to enter Instances of the Indicators in Protege.

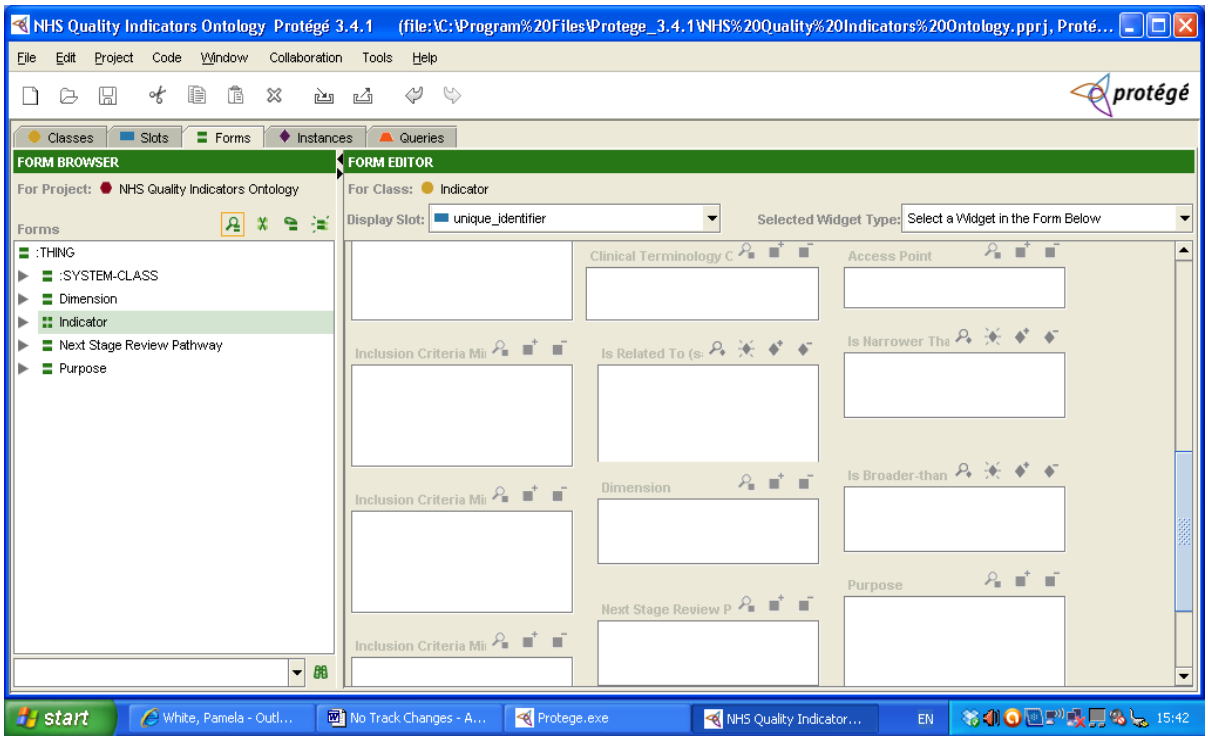

Figure 4.3. Second part of the form to enter Instances of the Indicators in Protege.

An Issues Log (Appendix 6) was created to track problems with using Protege and with the ontology development. This log shows the date the issue was discovered, a description of the issue, the date the issue was resolved, and how the issue was resolved

4.4.4 Instances

Following creation of the ontology framework of classes, subclasses, slots, subslots and forms, instances of the quality indicators were entered into the ontology. This involved entering metadata supplied by the NHS IC for each indicator into the forms. Appendices 3-5 were used to categorise relevant metadata from the NHS IC. The categorisation supported entry of instances.

4.4.5 The Ontology

The ontology is object-oriented, where properties are subordinate to classes and are modelled in terms of class A has Property (slot) P. Queries are used to gather information from the ontology, making it useful to clinical auditing communities, quality indicator developers, organisers of quality indicator sets and providers of access to quality indicator sets to reduce effort involved in healthcare quality monitoring. Clinical auditing communities, organisers of quality indicator sets and providers of access to quality indicator sets can search for quality indicators with common criteria, even though they are from different sources. Quality indicator developers may learn from the ontology by noting areas that could be simplified through more easily accessible and/or clearer metadata.

The software used to develop the ontology, Protégé 3.4.1, is freely available (Stanford Center for Biomedical Informatics Research 2014b). Although Protégé 3.4.1 is easy to learn, the resulting ontology could not be saved as a simple file. An attempt was made to make the ontology publicly available on the Internet via the National Center for Biomedical Ontologies website (Musen et al. 2012). The result was limited to a view of classes and subclasses, which has since disappeared from the website.

The ontology can be found in the CD attached to the back of this thesis. The user will need to install Protégé Frames 3.4.1 (Stanford Center for Biomedical Informatics Research 2014b). After installing Protégé 3.4.1, ask it to ***open a project***. The attached CD will need to have been inserted into the computer's CD drive. Select ***Open Other***, then the ***Pilot Ontology*** folder and the ***Protégé 3.4.1*** folder. Then select the ***NHS Quality Indicators Ontology pprj*** file.

Once you have opened the ontology, click ***cancel*** on the pop-up window that asks you to Choose an associated ChAO. Then click ***Close*** on the pop-up window that says *No ChAO*. The default screen shows the classes in the left frame. Click the ***triangle*** next to each class to view subclasses. There are ***tabs*** towards the top of the screen, above the frames, to view Slots, Forms, Instances and Queries. Subslots can be viewed if a triangle is to the left.

Instances have been entered for the Indicators class. ***Click on Indicator*** in the ***left frame*** and an Instance Browser frame will appear in the middle of the screen, showing unique identifiers for all 222 indicators. ***Click on one of the***

unique identifiers and its properties (slots) will appear in the right-hand frame, including relationships to other indicators.

End users involved in monitoring healthcare, will find the **Queries window** most useful, to **search for quality indicators from different sources** that have common criteria. After clicking on the **Queries tab**, three frames will appear: the Query frame, The Results frame and the Query Library frame. The upper left frame is the **Query frame**, where the query is entered, with sections to specify a class, slot and string. To add a class, click on the box icon with a plus sign above the text box under the word '**Class**'. Select the Indicator class. To add a slot, click on the box icon with a plus sign above the white space under the word '**Slot**'. Classes and slots must be specified before entering the desired string, so that Protégé knows where to look. The desired string may be typed directly in the text box. Classes and slots may be removed from the query by clicking the box with the minus sign above the Class and Slot text boxes. Clicking the magnifying glass icon above the Class and Slot text boxes results in a pop-up window with descriptive information for the class or slot selected. The query operator, '**contains**' may be changed by clicking the down-arrow next to the term. Other options include: '**does not contain**', ' **is**', '**is not**', '**begins with**', and '**ends with**'. Click on the Find button, in the bottom right corner of the Query frame to run the query. For example, Figure 4.4 shows a query for the term 'blood' in the Formula slot of the Indicators class. The **Results frame** shows a list of indicators with the word 'blood' in their formulae. Double-clicking on an indicator in the results list will call up a pop-up window, with information about the indicator.

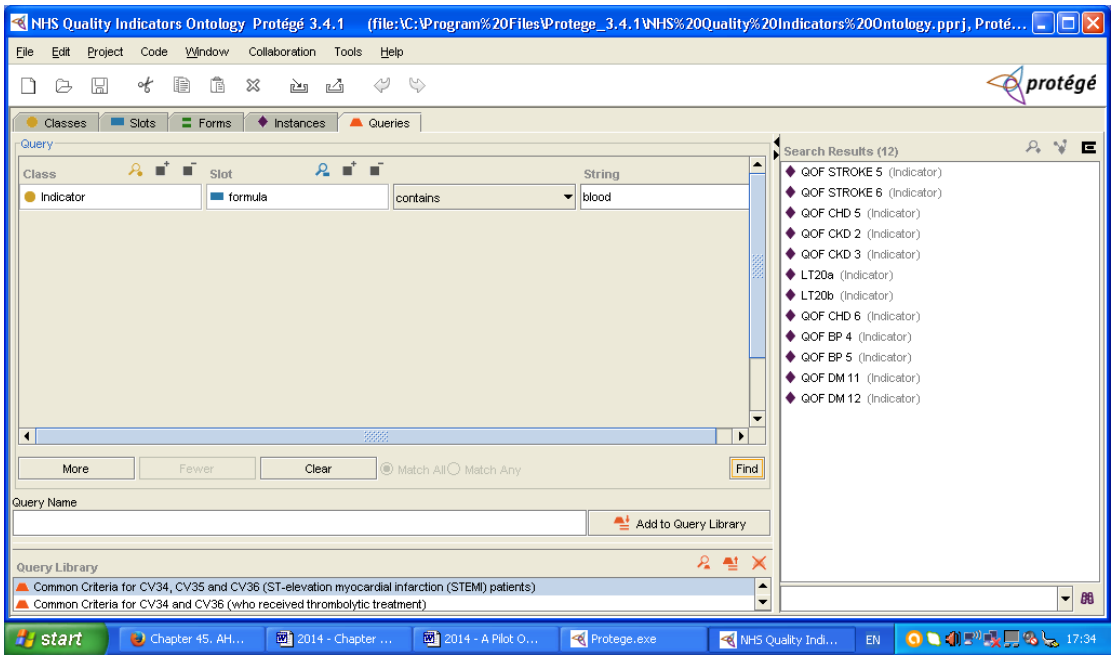

Figure 4.4. Query for Indicators with the Term 'Blood' in the Formula Slot.

Multi-part queries (eg, two terms, two different classes or two different slots) may be entered by clicking the **More** button in the bottom left section of the Queries frame. Queries may be saved by entering a title under **Query Name** in the **Query Library frame** towards the bottom left of the screen and clicking the **Add to the Query Library** button towards the bottom right of the Query Library frame.

4.5 Summary

This chapter has presented the results of the application of Methontology to develop a pilot ontology for the 2009 set of healthcare quality indicators provided by the NHS Information Centre (2009a). An attempt was made to specify inclusion and exclusion criteria, along with relationships between quality indicators and categorisation of indicators by Institute of Medicine (Field and Lohr 1992) purpose. Conceptualisation was the primary component

of preparation for development of the ontology itself. A Glossary of Terms was created to support identification of the metadata for individual indicators. Quality indicator dimensions and pathways, categorisation of the indicators by type and purpose, along with related indicators; and layers of inclusion and exclusion criteria for each indicator were noted as tables in appendices in this thesis. The formalisation of the ontology involved creating classes, slots, instances and test queries, using Protégé 3.4.1. Use of the ontology, including searching for indicators with common criteria has been described. The next chapter continues the results of the ontology development in the form of evaluation.

Chapter 5 Results: Evaluation

This chapter covers the evaluation of the ontology. Five common evaluation criteria (Gruber 1993a) are applied, including consistency, completeness, expandability, conciseness, and sensitiveness. Competency questions, to assess whether the ontology achieves its intended purpose, are answered. Metrics described by the US National Center for Biomedical Ontology (Musen et al. 2012) are calculated. The ontology was made publicly available for comment. Experts were contacted to review the ontology and stakeholders were consulted regarding the usefulness of this research.

5.1. Consistency

Consistency, with respect to ontology evaluation, refers to lack of conflict in definitions. Appendix 7 shows the definitions for the classes and subclasses in the ontology. Appendix 8 shows the definitions for the slots and subslots. For example, the definition for the class of Dimension is "Aspect of quality; identified from Darzi's (2008) UK Department of Health report, collating vision from 10 UK Strategic Health Authorities." There is some inconsistency in the definitions, in that the definition for Formula is "Calculation methodology for determining indicator data result" and the definition for Inclusion/Exclusion Criteria, which is a subclass to Formula, is "The inclusion and exclusion criteria are generally taken from the indicator Statement, due to metadata inconsistencies." Bearing in mind that the information for Formula is not always taken from the indicator Statement, there could be conflicting information, for example, more detail that could add to the criteria for

inclusion. Examples, rather than definitions, are given for the subclasses of the class, Purpose. This could potentially interfere with the consistency of the ontology.

5.2 Completeness

Completeness refers to the availability of information for definitions, whether this is explicit or inferred. This ontology is incomplete in that not all that is in the ontology is explicitly stated. Nor can the missing information necessarily be inferred from information that is included in the ontology. For example, the slot, Access Point, has a definition of "Location(s) of results of indicator assessment." This definition does not include all the possible locations of the results of indicator assessment.

Completeness can also be assessed through development of competency questions as a frame of reference. These questions should be designed to test whether the ontology fulfills its purpose. Competency questions developed for this ontology are shown in 5.6.

5.3 Expandability

Expandability refers to whether new definitions may be added without compromising definitions that have already been created. New definitions may be added to this ontology. However, classes, slots and instances may need to be reviewed to keep redundancy to a minimum and to identify any relationships. For example, definitions from GLIF were ruled out during the

Integration component of Methontology, due to appearing incompatible with definitions chosen from the NHS HSCIC's Metadata Guide, US Institute of Medicine's purposes for guidelines (Field and Lohr 1992) and Darzi's Next Stage Review (2008). The ontology may require significant reorganisation to accommodate the following GLIF definition: "Patient_State_Steps serve as entry points into the guideline as well as allow for labeling patient states (e.g., a state of taking one anti-hypertensive drug) (Peleg 2004b)." If Patient_State_Steps becomes a slot, there would be redundancies with information entered for Inclusion/Exclusion criteria. A similar issue would arise with the incorporation of the GLIF definition: "The Action_Step class is used for modelling actions to be performed. Action steps contain tasks. Two distinct types of tasks can be modelled: medically oriented actions such as a recommendation for a particular course of treatment, and programming-oriented actions such as retrieving data from an electronic patient record…." Again, there would be redundancies with Inclusion/Exclusion criteria.

5.4 Conciseness

Conciseness refers to whether the ontology provides useful and precise information. Redundancies are allowed, provided they are necessary to the ontology. There are some redundancies in this ontology. Next Stage Review Pathway, Dimension, and Purpose are all designated as classes as well as slots. This was deemed necessary because although they are properties of Instances of the class Indicators, they are also primary concepts in the ontology, with subclasses in their own right. While the Dimension subclasses

have slots, they currently have no Instances and therefore their slots appear to have no use.

5.5 Sensitiveness

Sensitiveness refers to how small changes to a definition could alter properties that have already been specified. An ontology is said to be sensitive if its architecture might be altered with small changes to a definition. Changes to a definition after it has become linked to already-defined properties will require a review of relationships and inclusion/exclusion criteria. If the definition for Purpose is modified to encompass a different set of potential indicator purposes, for example the categories used by the US National Guideline Clearinghouse (see 6.2.2.2, Conceptualisation: Categorisation of Indicators by Purpose), the properties (slots) would need to be respecified. Therefore, this ontology has high sensitivity.

5.6 Competency Questions

The competency questions in this section are intended to show the types of questions this ontology seeks to answer and to confirm that it achieves its purpose. The purpose of this ontology is to support reduction/duplication of workload in gathering data for quality indicator monitoring. Additionally, the ontology is intended to answer the research questions asked in this thesis:
1) What attributes of health care quality indicators influence the development of an ontology that emphasises specification of inclusion and exclusion criteria, along with specification beyond screening and prevention?

2) What relationships between health care quality indicators identify complexity of indicator relationships?

Questions 5.6.1, 5.6.2 and 5.6.5 involve related indicators and are intended to address the second research question. Questions 5.6.3 and 5.6.4 and 5.6.6 through 5.6.10 involve inclusion criteria, exclusion criteria, and indicator purposes, and are intended to address the first question.

5.6.1 Which of this set of NHS healthcare quality indicators share some of the same criteria?

The question may be answered by conducting a keyword query of the ontology, specifying a class of Indicators and a slot specific to the required criteria. For example, Figure 5.1 shows a query for indicators with the word blood in the slot Formula. Double-clicking on the name of an indicator in the Results frame causes a new window to pop up, with the full information on that indicator (Figure 5.2).

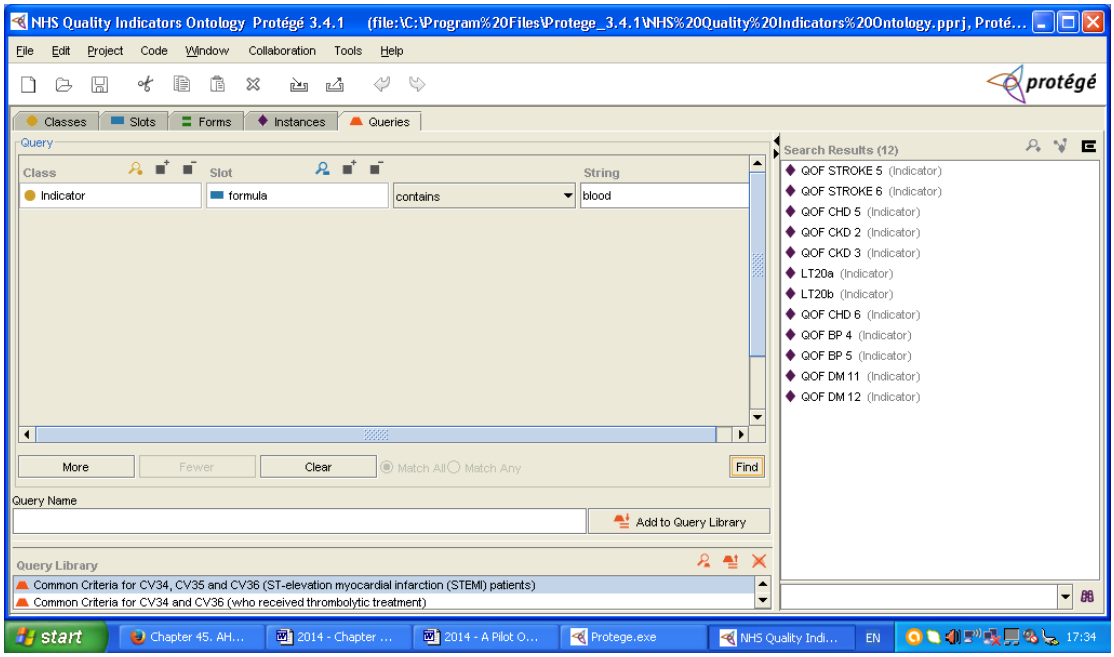

Figure 5.1 Query for Indicators with the Term 'Blood' in the Formula Slot.

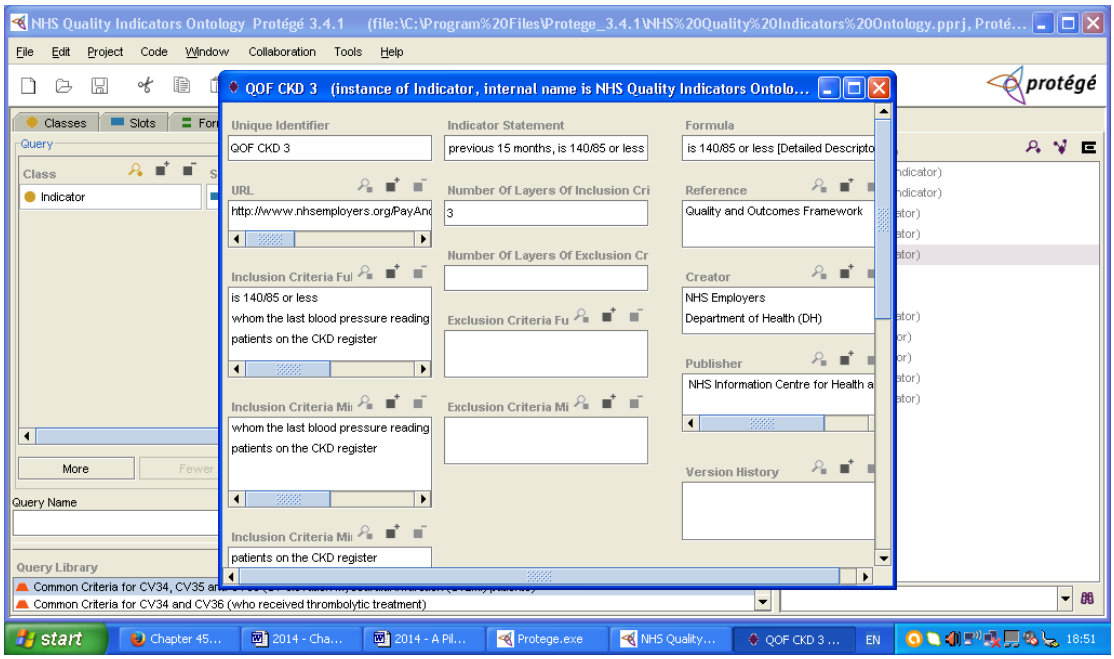

Figure 5.2. Pop-up Window for QOF CKD 3, one of 12 indicators listed in the results for the Query for Indicators with the Term 'Blood' in the Formula Slot.

5.6.2 Which of this set of NHS healthcare quality indicators share broader or narrower criteria?

The ontology is partially successful in answering this question. A query for each instance of the class Indicators for the *Broader or Narrower Than* slots may be created to find indicators that have broader or narrower criteria than the indicator specified in the query. There does not appear to be a Wildcard option in Protégé 3.4.1 to create a query to find all indicators with a particular slot that has information entered. To create a list of all indicators that have broader or narrower criteria than other indicators in the set, a query would need to be entered for each of the indicators.

5.6.3 Which of this set of NHS healthcare quality indicators have inclusion criteria containing a particular term or set of terms?

This question can be answered by creating a query using key terms for the slot Inclusion Criteria Full for the Indicators class. Figure 5.3 shows a sample query showing common inclusion criteria for cardiac infarction (STEMI) patients. Figure 5.4 shows a sample query showing common inclusion criteria for thrombolytic treatment.

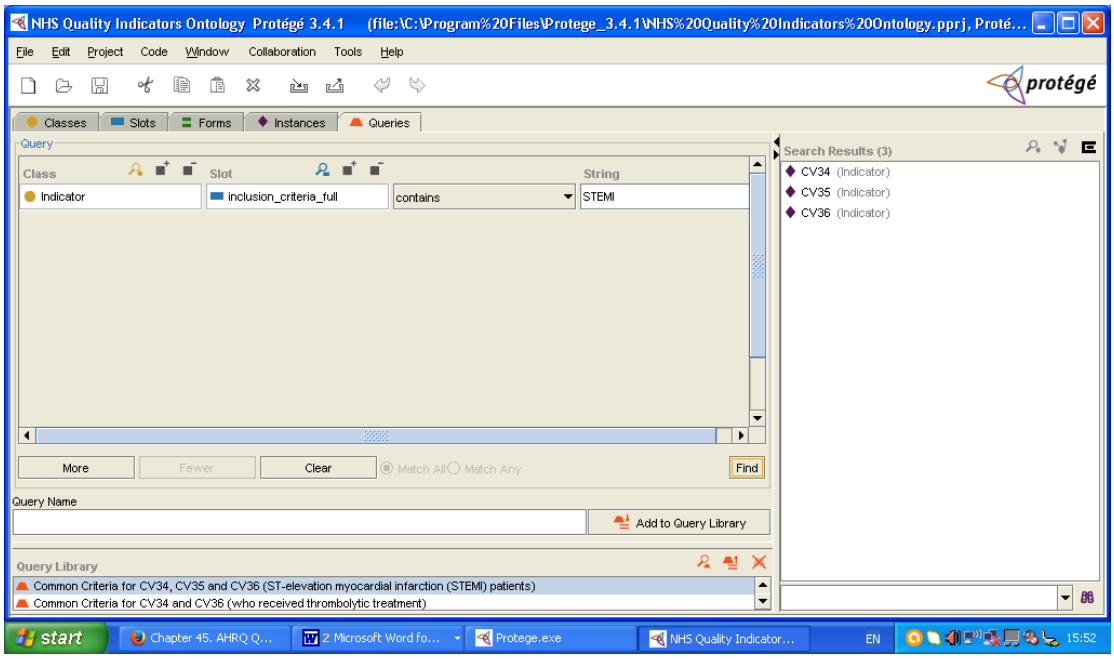

Figure 5.3. Query showing common inclusion criteria for cardiac infarction (STEMI) patients.

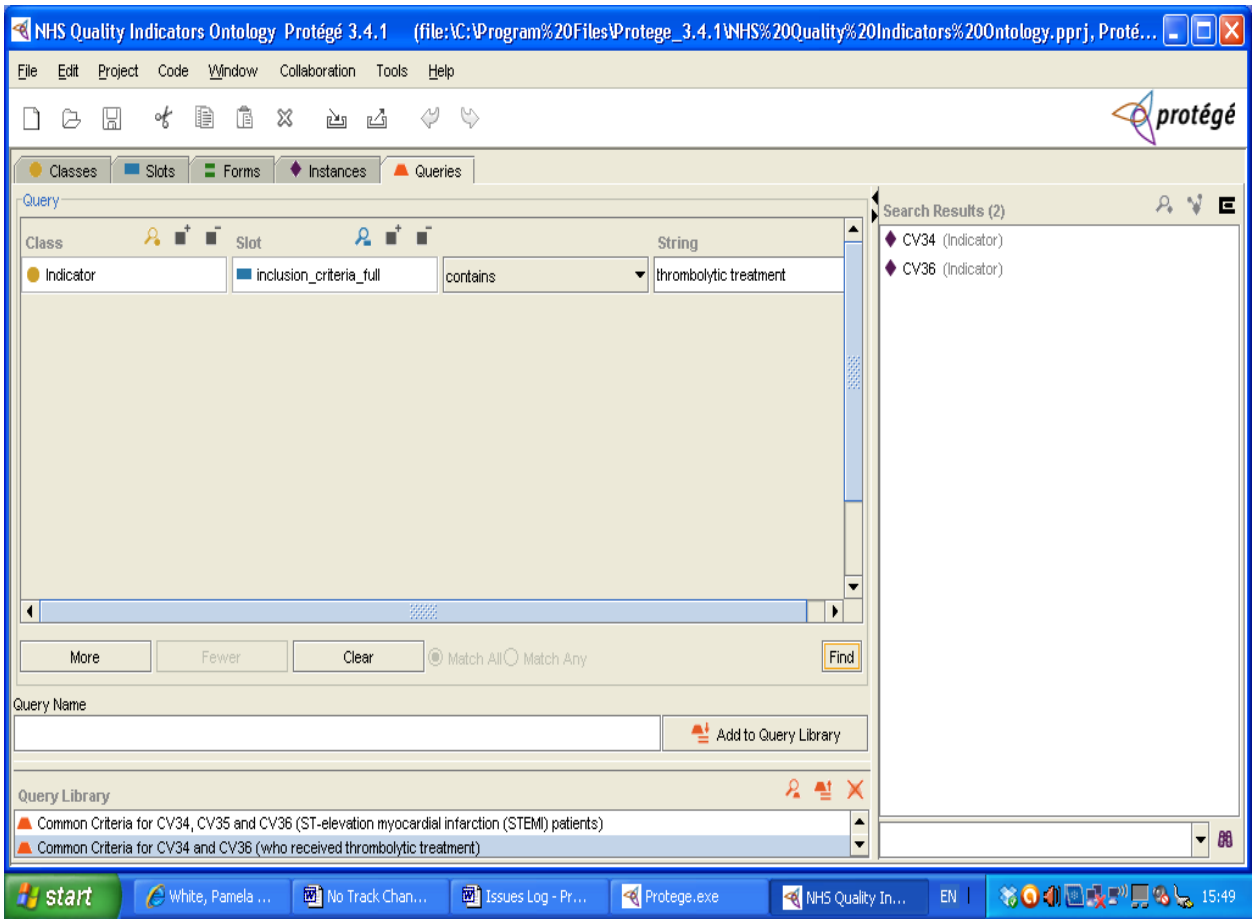

Figure 5.4. Common inclusion criteria for indicators involving thrombolytic treatment.

5.6.4 Which of this set of NHS healthcare quality indicators have exclusion criteria containing a particular term or set of terms?

This question can be answered in a manner similar to 5.6.3, specifying

Exclusion Criteria Full as the slot.

5.6.5 How many of this set of NHS healthcare quality indicators are in a particular indicator set and in a particular care pathway?

This question can be answered with two queries, linked using the *More* button

below the query frame. Figure 5.5 shows a query for indicators with a

reference set from NICE that are in the Next Stage Review Pathway of Planned Care.

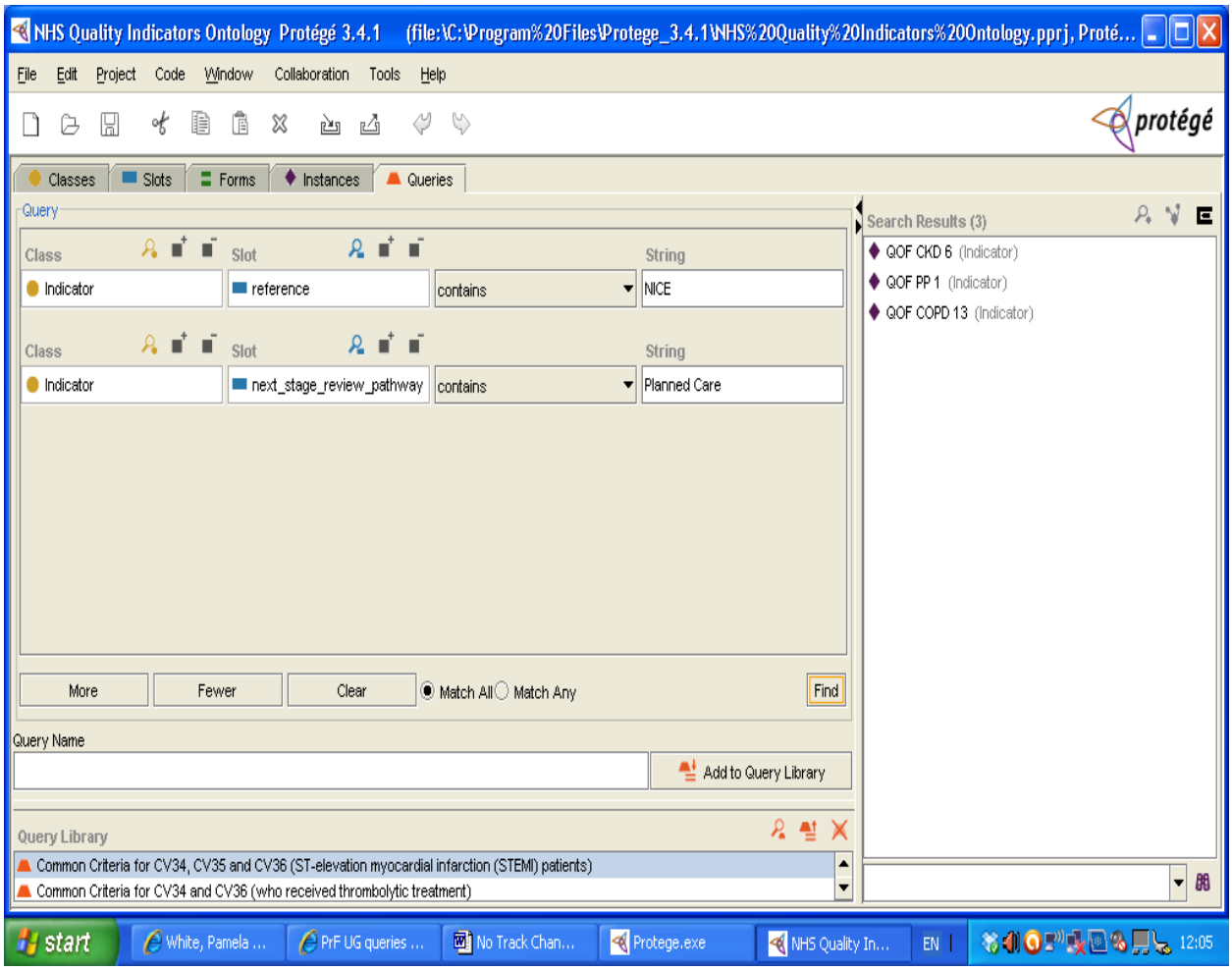

Figure 5.5. Query for indicator sets from NICE that are in the Planned Care clinical pathway.

5.6.6 How many indicators can be categorised by each Institute of Medicine purpose for clinical practice guidelines?

This question is answered by creating separate queries for each Institute of Medicine category of purpose. By querying the class of Indicator and Slot of Purpose, with a keyword of *Screening*, we find that there are 28 indicators in this set that have a common purpose of Screening and Prevention. Figure 5.6 shows the query and results. Figure 5.7 shows that there are twenty-one

indicators with a purpose of Diagnosis and Prediagnosis of Patients. Figure 5.8 shows that there are four indicators with a purpose of Indications for the Use of Surgical Procedures. Figure 5.9 shows that there are twenty-five indicators with a purpose of Appropriate use of specific technologies and tests as part of clinical care. Figure 5.10 shows that there are 148 indicators with a purpose of Indicators for care of clinical conditions.

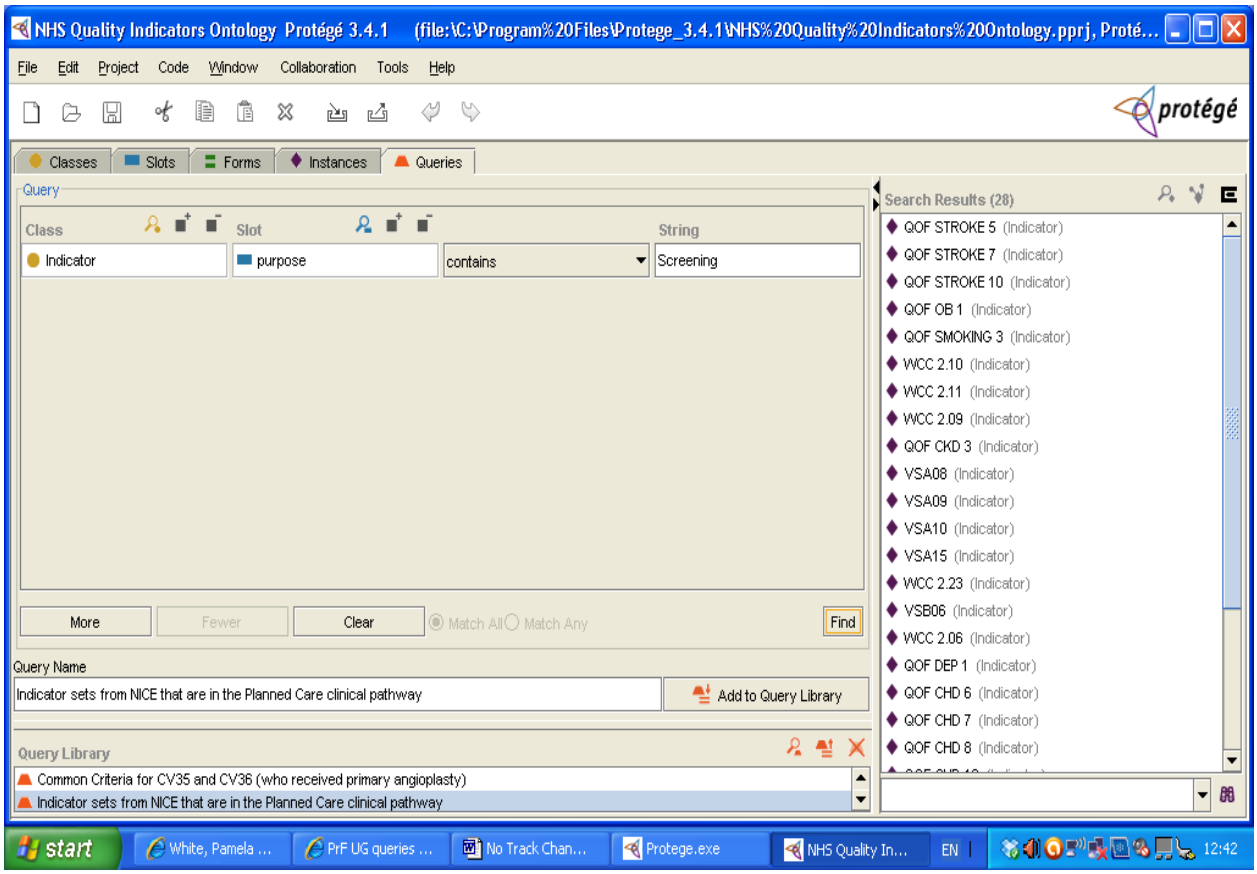

Figure 5.6. Query for Indicators with a purpose of Screening and Prevention.

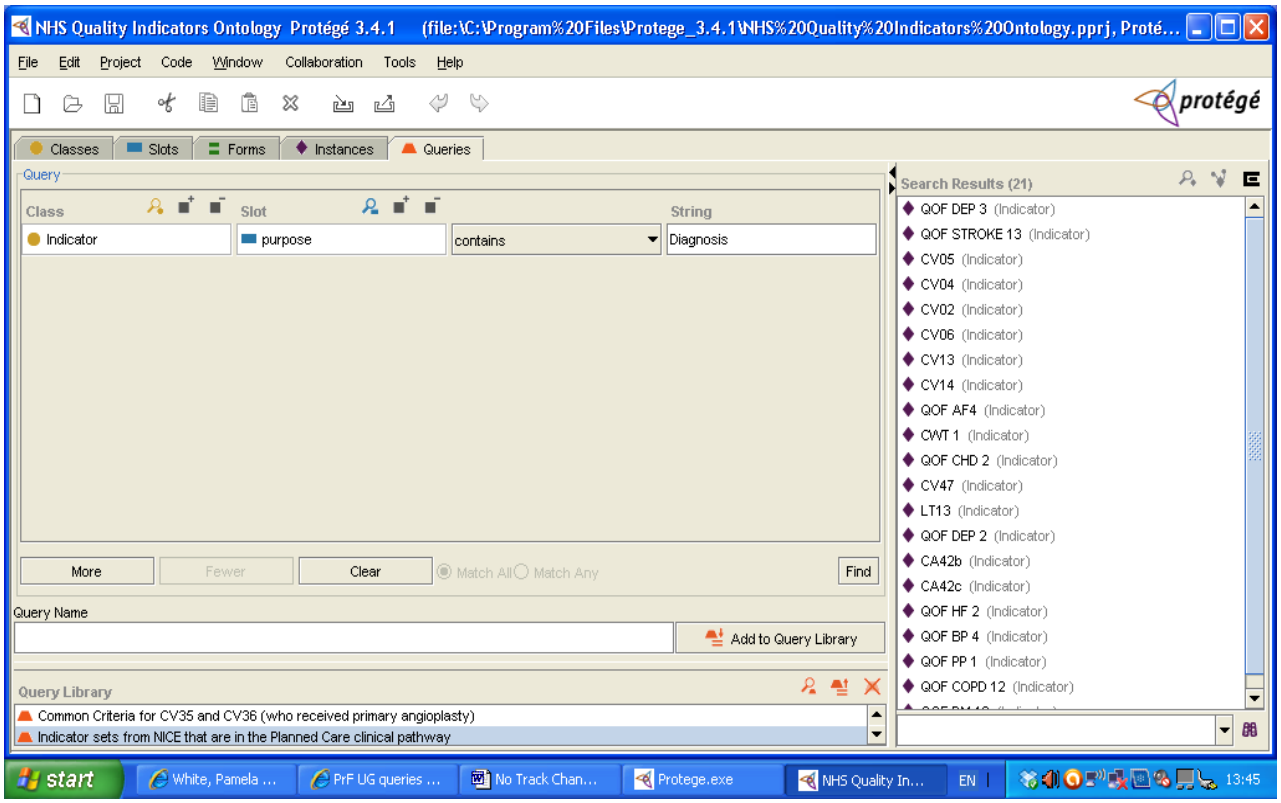

Figure 5.7. Query for indicators for Diagnosis and Prediagnosis of Patients.

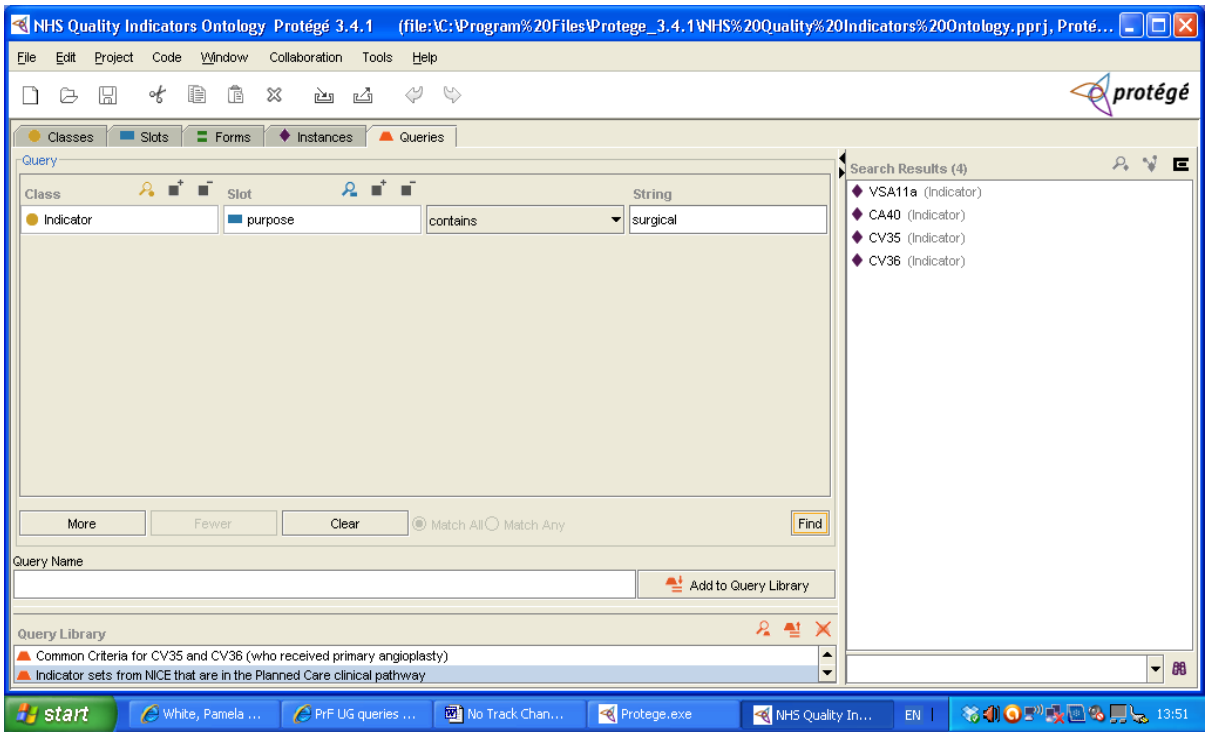

Figure 5.8. Query for indicators with a purpose of Indications for the Use of Surgical Procedures.

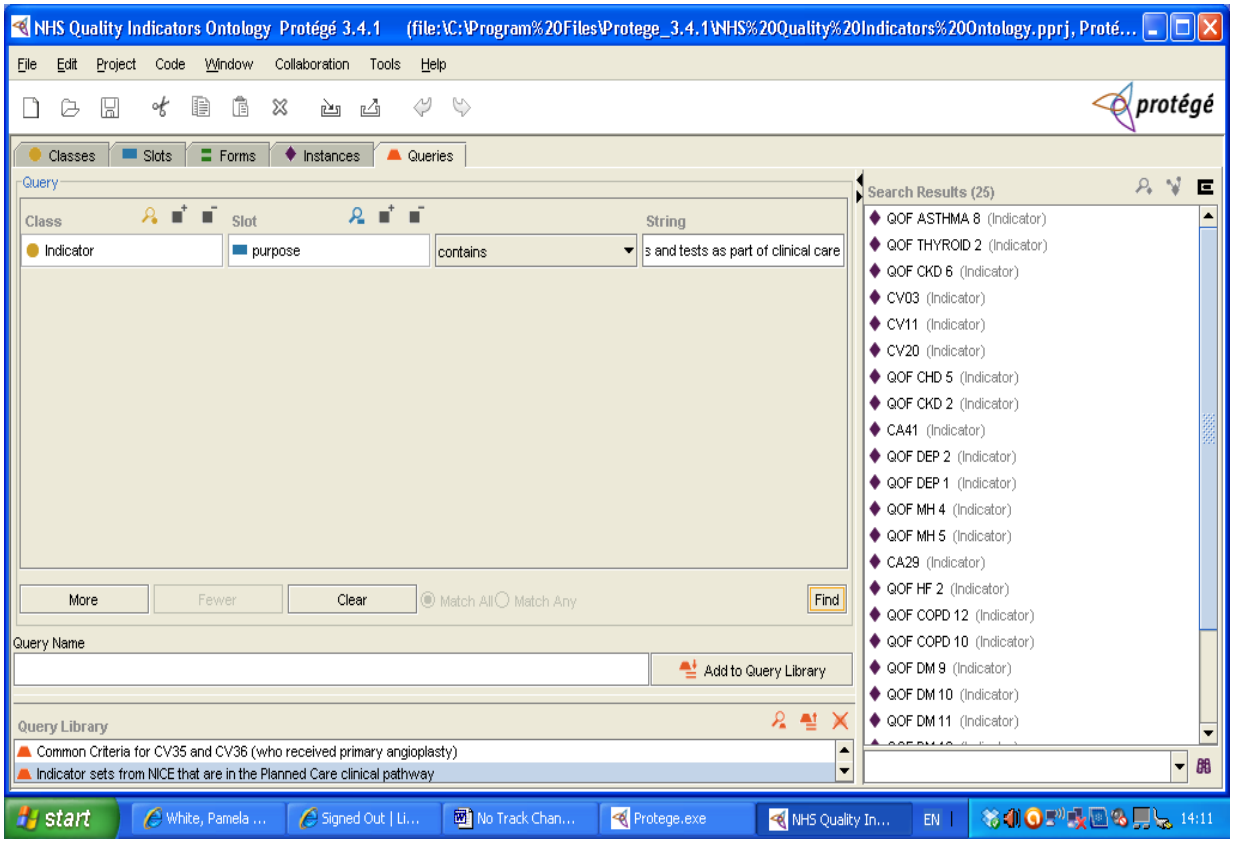

Figure 5.9. Query for indicators with a purpose of Appropriate use of specific technologies and tests as part of clinical care.

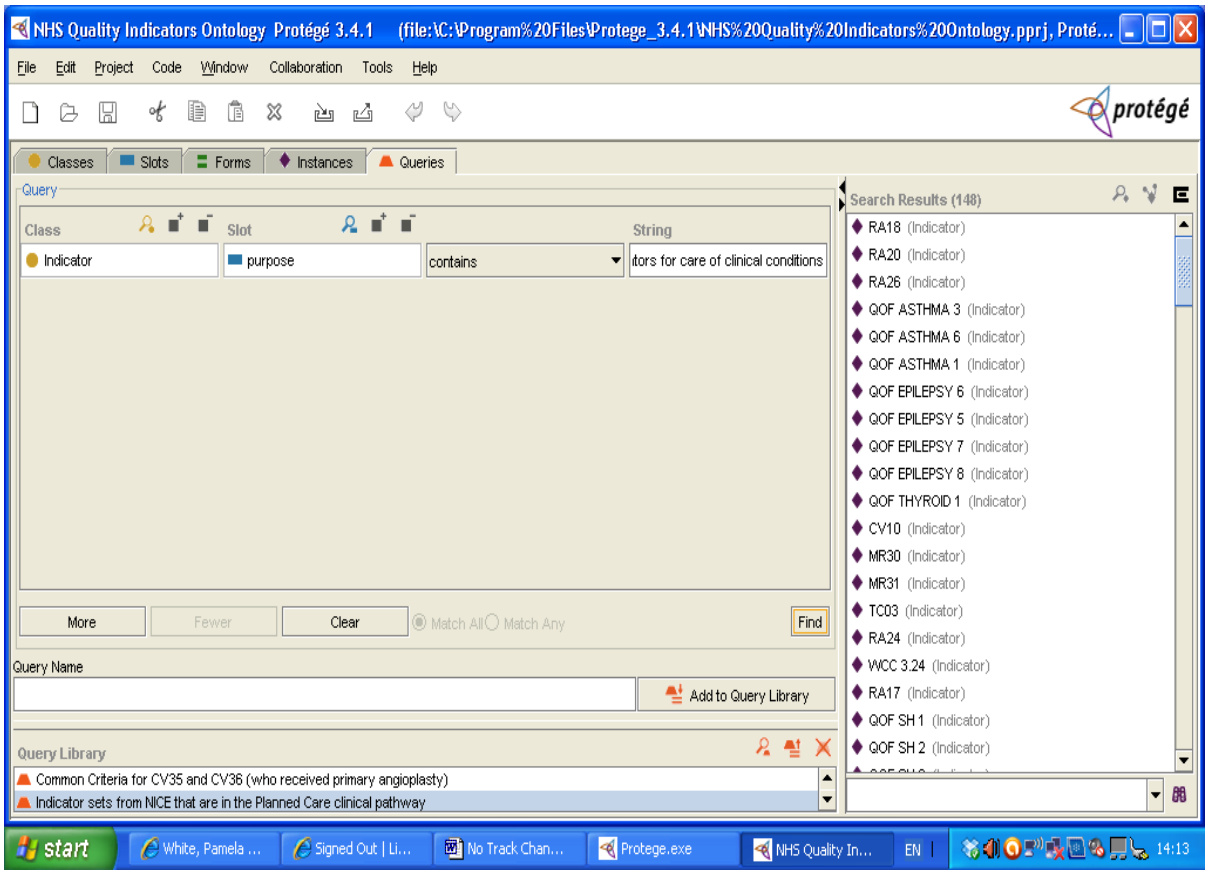

Figure 5.10. Query for indicators with a purpose of Indicators for care of clinical conditions.

Table 5.1 summarises the Number of Indicators by Institute of Medicine (Field and Lohr 1992) Clinical Guideline Category.

Category	Number of indicators
Prevention and Screening	28
Diagnosis and prediagnosis management of patients	21
Indications for use of surgical procedures	4
Appropriate use of specific technologies and tests as part of clinical care	25
Indicators for care of clinical conditions	149

Table 5.1. Number of Indicators by Institute of Medicine Clinical Guideline Category (Field and Lohr 1992)

Six indicators shared joint IoM criteria, three of which paired Diagnosis and prediagnosis management of patients with Appropriate use of specific technologies and tests as part of clinical care.

5.7 Metrics

Calculations have been made for the following metrics for ontologies (Musen et al. 2012): number of classes, number of individuals, number of properties, maximum depth, maximum number of siblings, average number of siblings, classes with a single subclass, classes with more than 25 subclasses, classes with no definition. These statistical metrics (Noy and McGuiness [2002]) identify baseline information for the ontology, enabling others to compare ontology characteristics. These metrics may also be used to identify potential modelling deficiencies and/or completeness of the ontology.

5.7.1 Number of classes

A class is “a concept in the domain of the ontology” (Musen et al. 2012). There are 4 classes, with 18 subclasses. These are listed in Appendix 7.

5.7.2 Number of individuals

Individuals are instances of each class. There are 222 individuals.

5.7.3 Number of properties

Properties are slots, including subslots. There are 39 properties. The slots and subslots are listed in Appendix 8, Slots and Subslots.

5.7.4 Maximum depth

Maximum depth refers to the maximum depth of the hierarchy tree of classes, subclasses, slots and subslots. Parent-child type relationships are considered to measure depth of the hierarchy tree. There are 7 subslots for the slot, Inclusion/Exclusion Criteria. This is the maximum depth of this ontology.

5.7.5 Maximum number of siblings

Maximum number of siblings refers to the maximum number of siblings at one level in the hierarchy tree. This includes classes and subclasses, slots and subslots. There are a maximum of 17 subslot siblings for the class, Indicators. Most of these are assigned to different slots, which are all assigned to the Indicators class.

5.7.6 Classes with a single subclass

A class, previously defined as “a concept in the domain of the ontology” (Musen et al. 2012), with only one direct subclass, is a sign there may be a modelling problem or that the ontology is not complete (Noy and McGuiness [2002]). There are no classes with a single subclass.

5.7.7 Classes with more than 25 subclasses

More than a dozen subclasses for a given class indicate that additional intermediate categories may be necessary (Noy and McGuiness [2002]). There are no classes with more than 25 subclasses.

5.7.8 Classes with no definition

Definitions for each of the classes are shown in Appendix 7, Classes and Subclasses. There are no classes with no definition.

5.8 Public Availability, Stakeholder Consultation and Expert Review

The ontology was made available for public comment at: http://bioportal.bioontology.org/ontologies/3243. No comments were received. A limitation of the public version of the ontology is that properties and instances are not displayed, leaving very little on which to comment. It is noted that few, if any, comments were made on any of the ontologies available at the National Center for Biomedical Ontology (Musen 2012)

website and that access to the limited view of classes and subclasses for this ontology is no longer available.

Stakeholders, including EHR vendors, NHS staff and representatives from NICE and the NHS HSCIC were consulted regarding the usefulness of the ontology. Two academic Health Informatics experts examined the ontology. Two EHR vendors expressed interested in the ontology. Both vendors have dashboard components in their software. At least one of the vendors currently emphasises clinical practice guidelines, rather than quality indicators, in their dashboard.

A former NHS staff member, whose work had emphasised clinical governance, commented that the ontology could be very useful, as he had previously spent large amounts of time reading through full text documentation to ascertain necessary components for quality monitoring. A Director for the NHS South Commissioning Support Unit was more concerned with taking action over outcomes, rather finding and extracting data. Emails were sent to the NHS HSCIC and to NICE, requesting a discussion of the usefulness of this research. Although the email to the HSCIC was acknowledged, no discussion was scheduled. Academic experts in Health Informatics from Chile and the UK were willing to comment on the ontology. The Chilean expert gave similar feedback to the assessments made in 5.1 – 5.5 in this chapter, including some concern regarding the overlap between slots and classes. The UK expert suggested that the number of slots could be

reduced and that perhaps the Indicators could be browsed in different ways and tailored to stakeholders.

5.9 Evaluation Conclusions and Future Ontology Development

Common evaluation criteria for ontologies appear heavily influenced by the platform chosen for ontology development and by the availability of metadata for conceptualisation. Protégé 3.4.1 allows designation of concepts to be slots as well as classes, thus allowing for redundancies and reducing conciseness. Instability of NHS information points interfered with completeness in that slot instances cannot be completely specified with any long-term certainty.

The next step in development of this ontology would be to find more experts willing to comment on the ontology. Discussions with appropriate representatives from NHS healthcare stakeholders, particularly the NHS HSCIC, would benefit revision of the ontology. A more recent indicator set could be used for the next ontology and compared with the development of the ontology for the 2009 indicator set.

5.10 Summary

This chapter has presented an evaluation of the ontology including consistency, completeness, expandability, conciseness, and sensitiveness. Competency questions were answered. Metrics were calculated. The ontology was made publicly available for comment, stakeholders were consulted and

future opportunities for evaluation were discussed. The next chapter will offer a discussion of the ontology development process and of the ontology itself.

Chapter 6 Discussion

This chapter provides a discussion of the ontology development process and the ontology itself. Included is a discussion of the purpose of the research, choice of indicator set, methodology and platform chosen to develop the ontology. Evaluation of the ontology and research limitations are also discussed in this chapter.

6.1 Purpose of Research and Choice of Indicator Set

Although the motivation was to create an ontology that can reduce duplication of effort in NHS healthcare quality monitoring, this research project was exploratory in nature, emphasising feasibility and underscored by the research questions stated in Chapter 1:

1) What attributes of health care quality indicators influence the development of an ontology that emphasises specification of inclusion criteria, along with specification beyond screening and prevention?

2) What relationships between health care quality indicators identify complexity of indicator relationships?

The set of over 200 indicators was chosen to attempt to address some of the gaps in the research identified in Chapter 2's literature review. The gaps included research on healthcare quality indicator purposes, an ontology for healthcare quality indicators that is not dependent on data available in EHRs, a healthcare quality indicator ontology that covers many clinical subject areas, and a healthcare quality indicator ontology that does not require indicator

developers to fit into a framework. The literature review found that, along with being data-dependent, Arden Syntax may be limited to the purpose of screening and prevention (Ohno-Machado et al. 1998). Arden Syntax (Jenders 2008) and Surján's (et al. 2006) ontology for Public Health Indicators were applied to a subject-specific indicator set. The US Quality Data Model (2008) requires indicator developers to fit into a specified framework.

6.2 Ontology Development Process

6.2.1 Approach to Ontology Development

Methontology was chosen as the method to develop the ontology. This evolving approach worked well. Iterative in nature, Methontology allowed scope for backtracking and exploratory work. The exception to the flexible application of this method was the Evaluation component. Much of the evaluation criteria, including metrics and competency questions, could not be properly applied until the ontology was considered complete, at a minimum of a pilot stage. This limited practical application of the Evaluation component of Methontology to primarily the end stage of the ontology development, rather than throughout the development lifecycle.

6.2.2 Conceptualisation

Conceptualisation played an important role in the identification of attributes and relationships of this set of quality indicators. The next four sections, 6.2.2.1-6.2.2.4, describe the conceptualisation for indicator Dimension and

Next Stage Review Pathway, Purpose, Clinical Code, and Inclusion/Exclusion criteria. Indicator Purpose and Dimension and Next Stage Review Pathway were identified as both classes and slots in this ontology, due to their being properties of the indicators and their use to categorise the indicators. Clinical Code and Inclusion/Exclusion criteria were identified as properties of the indicators. While some of the slots assigned to the Indicators class, such as Unique Identifier, were easy to conceptualise, Clinical Code and Inclusion/Exclusion criteria were complex, with more options for organisation than other properties of the indicators.

6.2.2.1 Conceptualisation: Dimensions and Next Stage Review Pathway

The US Institute of Medicine's highly cited "Crossing the Quality Chasm…" report (2001) specifies six domains of healthcare quality: safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity. The first three of these domains are the same as the dimensions specified in the Darzi report (2008) used by the NHS Information Centre to help categorise the 2009 set of indicators. The similarity between the IoM's domains of healthcare quality and the UK domains supports the use of Darzi's categories to classify the indicators. Darzi's Dimensions are: Effectiveness, Safety and Experience. Darzi's Pathways are: Acute Care, Children's Health, End of Life Care, Learning Disabilities, Long Term Conditions, Maternity and Newborn, Mental Health, Other, Planned Care and Staying Healthy.

The number of indicators for the clinical pathways identified in Darzi's Next Stage Review report (2008) were identified by the NHS IC in Table 4.3. A logical next step was to name the indicators in each of the pathways with a goal of making searching for indicators in a particular pathway possible in the ontology. Appendix 3 shows categorical sorting for the quality indicator Dimensions and Next Stage Review pathways for each indicator.

6.2.2.2 Conceptualisation: Categorisation of Indicators by Purpose

Appendix 4 classes the indicators by purpose, with a summary of the Institute of Medicine's (IoM) purposes at the beginning of the appendix. Categorisation of the IoM (Field and Lohr 1992) purposes for guidelines to the set of indicators supported the hypothesis that Arden Syntax is inadequate to express different types of indicators. This categorisation showed that the most common purpose was indicators for the care of clinical conditions, rather than screening and prevention. Arden Syntax has been described as best suited for screening and prevention (Ohno-Machado et al. 1998). Indicators were indexed as specifically as possible in Appendix 4. Where more specific categories would be possible had the information given been more specific (eg, treatment vs surgery), this has been noted (eg, WCC 2.25, Percentage of patients waiting no more than 31 days for cancer treatment) [Treatment not specific enough - could be surgery, radiotherapy or other]).

Categorisation of the indicators also showed that their purposes are unevenly related. The broadest purpose is care of clinical conditions. Appropriate use of specific technologies and tests as part of clinical care is the second broadest

purpose. Screening and prevention, Diagnosis and prediagnosis management of patients and indications for use of surgical procedures are equally narrower than care of clinical conditions and appropriate use of specific technologies and tests as part of clinical care. Some indicators could be categorised with more than one purpose. Indicators with a purpose of diagnosis and prediagnosis management of patients that had more than one purpose were most often paired with appropriate use of technologies.

Two other categorisation systems worth considering for future healthcare quality indicator ontologies include those developed by the US National Guideline Clearinghouse (Agency for Healthcare Research and Quality [2012]) and those developed by the US National Quality Forum (2012b). The National Guideline Clearinghouse uses eleven categories, very similar to the IoM's, though with more easily identifiable individual components, to descibe the major focus of guidelines. The nine categories relevant to quality indicators are:

Assessment of Therapeutic Effectiveness

Diagnosis

Evaluation

Management

Prevention

Rehabilitation

Risk Assessment

Technology Assessment

Treatment

The National Guideline Clearinghouse categories were cited and expanded upon (Bernstam et al. 2000). However, the additional proposed categories, Clinical Trial and Risk Assessment, seem unnecessary for quality indicators. Bernstam's work was evaluated, concluding that 89 out of 100 National Guideline Clearinghouse guidelines could be classified within the same category (Bernstam et al. 2001). There is ongoing discussion of categorisation of quality indicators, along with the concern that if quality monitoring emphasises a particular area of quality monitoring, for example prevention and management of chronic disease, it may be to the detriment of other areas of quality monitoring, for example appropriate use of tests (Bishop 2013). Thus, both broad and narrow categories for healthcare quality indicators are advisable to provide an overview of the spread of areas of healthcare addressed by quality indicators.

The National Quality Forum's (2012b) Quality Data Model contains twenty-seven categories. The categories tend to be more specific to information likely to be available in EHRs than the Institute of Medicine or National Guideline Clearinghouse categories. The categories include attributes such as 'Admission Date and Time', 'Dosage' and 'Severity'. There is some overlap in these categories, including 'Radiation Dosage', which is narrower than 'Dosage'. The National Quality Forum category of 'Related To' was identified as a property of indicators for this ontology. Some of the National Quality Forum categories could be used in combination with broader categories from the National Guideline Clearinghouse or the IoM.

6.2.2.3 Conceptualisation: Clinical Codes

Clinical codes and their corresponding term(s), rather than NHS IC assigned Subject, were assigned to specify clinical components of the indicators. The NHS IC assigned subjects appeared arbitrary and ranged from clinical conditions to quality indicator set (eg, World Class Commissioning). Clinical areas were sometimes also covered under Topic, under the Planned Care element of the NSR Pathway within the NHS IC metadata scheme. By using Clinical Code as a subject-related slot, the ontology may, in the future, be useful for some quality-monitoring via EHRs. Data quality and availability has been criticised as a challenge for quality-monitoring via EHRs (Roth et al. 2009).

6.2.2.4 Conceptualisation: Inclusion/Exclusion Criteria

Relationships between indicators focussed primarily on relationships between inclusion criteria. Boolean logic was inconsistently applied for layers of Inclusion/Exclusion criteria, when the term ‘or’ appeared between concepts. For example, CV38 has one inclusion layer of Cardiac Rehabilitation Audit and one layer of exclusion criteria:

CV38 Inclusion Criteria	1) Submission of 20 cases or more per month OR more than 70% case ascertainment.
CV38 Exclusion Criteria	1) Submission of less than 20 cases per month

However, QOF STROKE 12 has four layers of inclusion criteria with a separate layer for one OR statement, but not another because both terms on either side of the word ‘or’ are tied to the same concept for one statement. Eg, A side effect may also be a contraindication. The other statement shows two

separate concepts on either side of the word ‘or’. Eg, ‘non-haemorrhagic is not the same as or similar to TIA.

QOF STROKE 12 Inclusion Criteria	1) patients with a stroke
	2) shown to be non-haemorrhagic,
	3) or a history of TIA,
	4) who have a record that an anti-platelet agent (aspirin, clopidogrel, dipyridamole or a combination), or an anti-coagulant is being taken
QOF STROKE 12 Exclusion criteria	1) unless a contraindication or side effects are recorded

Semantics in the text of some of the indicators also influenced the number of layers of Inclusion/Exclusion criteria. There were sometimes more concepts than layers, due to the likelihood of concepts being likely to be grouped together. These dependencies were recorded at same level. For example, ”*the number of doctors washing their hands between seeing patients”* shows a dependency between doctors and patients. “Access to scanning within 3 hours of admission” has two concepts that are recorded at same level because “within 3 hours of admission” must apply to scanning.

Semantics of indicator text also resulted in temporal issues being recorded inconsistently in this pilot. Levels of Inclusion/Exclusion criteria were recorded differently in the following two indicators, due to the use of parenthesis in the second indicator:

QOF BP 4

1) patients with hypertension
2) in whom there is a record of the blood pressure
3) in the previous 9 months

QOF BP 5
1) patients with hypertension
2) in whom the last blood pressure (measured in the previous 9 months)

3) is 150/90 or less

The record of blood pressure in QOF BP 4 appears less dependant on the date of measurement because the date range of measurement does not appear in parenthesis. QOF BP 5 notes that the last measurement must have occurred within the previous 9 months. This shows a greater dependency between the two concepts.

6.2.3 Integration

Integration of other ontologies included efforts to find relevant ontologies through literature searching and the National Center for Biomedical Ontology (Musen et al. 2012) website. UMLS was the most successful Integration component, though was not without challenges (see 6.2.4.1). An attempt to apply GLIF, an ontology for clinical practice guidelines, to a quality indicator, was unsuccessful. A possible solution to increased slot redundancies with the incorporation of definitions from GLIF could be to incorporate Look-up tables linking Inclusion/Exclusion criteria to their respective Step in GLIF or to use a newer, more flexible version of Protégé (eg, Protégé 4).

6.2.4 Formalisation

Formalisation, the frames-based creation of the ontology, involved creating classes, slots, forms and instances, using Protégé 3.4.1. Categorical sorting and repertory grid analysis were used to identify the classes and subclasses listed in Appendix 7 and the relationship slots and subslots listed in Appendix 8 (eg. Is Broader Than). The Glossary of Terms in Table 4.2, modified from the NHS Information Centre's Metadata Guide (NHS Information Centre

2009b), served as a starting point for the majority of slots and subslots. US Institute of Medicine Purpose for Guidelines (Field and Lohr 1992) and Lord Darzi's (2008) Next Stage Review dimensions and clinical pathways were applied to both classes/subclasses and slots due to their being concepts within the healthcare domain as well as attributes of quality indicators. Formalisation of the ontology was largely dependent upon available metadata, as metadata about the indicators was needed to enter Instances into the ontology. Formalisation for the Clinical Codes, Inclusion/Exclusion Criteria, Formula, and Reference slots is discussed in 6.2.4.1 – 6.2.4.4. Formalisation for Instances of the indicators is discussed in 6.2.4.5.

6.2.4.1 Formalisation: Clinical Codes

Difficulties with clinical coding included lack of medical expertise, lack of UMLS expertise, duplicate concepts for codes from different sources in UMLS and the granularity of indicator text not always being at the same level as the text corresponding to the most relevant clinical code. For example, QOF DM 23 included the phrase: "or equivalent test/reference range depending on local laboratory". Some ranges specified in indicators did not show as an option in UMLS, requiring general codes that resulted in the same coding for different indicators For example,, VSA09 had criteria of 'aged 53-70. The code wound up being very broad, C0001779, 'Age', as there was no code specific to the age range, 53-70).

In an attempt to comply with Bhensky's et al. (2011) recommendation to identify the version of any clinical terminologies used, a subslot to Clinical

Code, Clinical Terminology Code Version, was created. This subslot had to be deleted, as its status as a subslot does not accomplish the task intended. It inherited the superslot, but would not allow the user to attach a version. To identify terminology versions, the complete terminology for each coding system used would need to be integrated into the ontology, with a look-up feature. Surján et al. (2006) also found semantic limitations using Protégé to develop an ontology for Public Health indicators. They were unable to distinguish between a person who has died and the person who certified the death in their ontology.

6.2.4.2 Formalisation: Inclusion/Exclusion Criteria

Inclusion/Exclusion Criteria needed to be layered from full to minimum instead of 1st layer, 2nd layer, etc. because slots and subslots include content of narrower slots. Additional slots for Number of Inclusion Criteria and Number of Exclusion Criteria were added to handle queries based on Inclusion/Exclusion criteria. This was intended to compensate for backward nature of layers of criteria and to enable queries for related indicators to be structured from common and initial criteria inwards. Conceptually, the order for some levels of criteria sometimes mattered more than others. The reason for the concern was the ability to specify a particular layer of criteria, but not others. It was later decided that key-word searching the full set of layers would be sufficient.

The NHS HSCIC metadata field that most frequently contained exclusion information was Definition. This is in contrast to the location of inclusion criteria, which appeared in more than one field. While some exclusion criteria

appear to have been inconsistently applied in the metadata supplied by the NHS IC, the information may be inferred in other indicators where the information is not explicitly stated. For example, CA01 has inclusion criteria of

1) stroke patients
2) given Aspirin or alternative e.g. clopidogrel,
3) within 48 hours of stroke

and

exclusion criteria of:

"patient is receiving palliative care, OR patient died OR patient has an intra-cerebral haemorrhage."

The first two exclusion criteria may be applicable to many of the other indicators, but are not necessarily stated in those indicators.

Future versions of this ontology would benefit from development of rules or guidelines for specification of inclusion/exclusion criteria. This could at least partially address some of the semantic challenges in translating indicator text into ontology concepts. A smaller and/or more uniform indicator set would make it easier to identify inclusion criteria with greater accuracy, though would also defeat the purpose of this research.

6.2.4.3 Formalisation: Formula

While a referring URL was initially sometimes included in the ontology for the Formula slot, if a referring URL was supplied as the metadata for Formula by the NHS IC, this was later changed to the text from a slot with relevant text (eg, QOF PC2, "The practice has regular (at least 3 monthly) multidisciplinary

case review meetings where all patients on the palliative care register are discussed"). The variability in the source of information for what the NHS IC refers to as 'Formula/Calculation/Methodology' may be due to some indicators being calculated as fractional formulae and some indicators being calculated via a ratings system (eg, PE 49, "Score for patients who reported that the hospital room or ward was very or fairly clean"). Due to inconsistencies in the information supplied by the NHS IC, the formula was sometimes taken from the Detailed Descriptor, Statement or Definition section of the NHS IC metadata; whichever had the most relevant and succinct information. The source for the formula is given in brackets in the Formula slot for each indicator in the ontology. The metadata for Statement, Detailed Descriptor, Definition and/or Formula/Calculation/Methodology are sometimes the same. When this occurs, only one source is noted.

6.2.4.4 Formalisation: Reference

The column, Indicator Set or Creators, in Appendix 3, Quality Indicator Dimensions and Next Stage Review Pathways, lists the information used to fill in the Reference slot in the ontology. The information for this slot was taken from the NHS IC Source metadata. Inconsistencies in metadata for NHS IC Source names meant that some set names may be unreliable or that the indicator is not part of a named set. The NHS IC Source information for LT13-22 is an example of variations in metadata. Sometimes Source is listed as UK Renal Registry. Sometime it is listed as National Renal Dataset. Therefore, the set name was sometimes replaced by the imputed author of the formula for the indicator. Sometimes there is more than one party

responsible for the development of the indicator. This is the reason for including alternate information in the third column in Appendix 3. Reliability of the Reference/Source information could be improved by developing authority records for the parties involved in quality indicator development and use. Authority records trace history and variations in name changes.

6.2.4.5 Formalisation: Instances

Prior to entering instances, a Snapshot rule was created to address different status levels of the indicators. If an indicator had a status of ***Dropped*** at the time of recording data into Appendix 3, the instance was not entered into the ontology. If an indicator had a status of ***Dropped*** after it was recorded into Appendix 3, the indicator was entered as an instance into the ontology. If an indicator had a status of ***Replaced by***, at the time of recording into Appendix 3, the indicator was not entered into the ontology. If an indicator had a status of ***Replaced by*** after recording the indicator into Appendix 3, it was entered into the ontology. Relationships and sometimes URL are not given in Appendix 3 if indicator is no longer in use.

6.3 Platform

Protégé 3.4.1 was a good choice for someone new to ontology development to organise this set of indicators. More abstract capabilities offered by newer versions of Protégé would reduce redundancies caused by duplication of Dimension, Next Stage Review Pathway and Purpose as both Classes and Slots. However, newer versions of Protégé lacked appropriate training

materials for people new to ontology development. A recent comparative view of versions of Protégé offers recommendations for different versions of Protégé, depending on purpose (Stanford Center for Biomedical Informatics Research 2013). Given that Frames support was not yet available for Protégé 4, Protégé 3.4.1 should be viewed as appropriate for this research, noting that Protégé 3.5 was not yet available at the time of this project.

6.4 Evaluation

Evaluation of ontologies is difficult, in part, due to differing definitions of ontologies and different development platforms. There does not appear to be a single preferred method of evaluating ontologies (Gruber 1993a, Gomez-Perez 2004, Rogers 2006). The methods selected to evaluate this ontology, included assessment of consistency, completeness, expandability, conciseness, and sensitiveness; competency questions, to assess whether the ontology achieves its intended purpose; and metrics. The ontology was made publicly available for comment and stakeholders and academic experts were contacted to comment on the ontology.

6.4.1 Consistency and Completeness

Consistency of definitions of classes and subclasses should be reconsidered if this pilot ontology is revised. Explanatory information and examples are sometimes given in place of a pure definition in the current ontology. It may be useful to compare the consistency of the definitions for this ontology with consistency of definitions for ontologies for clinical practice guidelines.

Completeness of definitions could also be improved, though this may not be possible for some definitions. Given the ever-changing nature of the NHS and related organisations, it is unlikely that a list of all possible options to fill certain slots, eg, Access Point, would remain current and complete.

6.4.2 Expandability

Expandability is limited by the classes and slots already defined within the ontology. New definitions may be added if they are assessed against current definitions for redundancy and/or contradictory information. The Dimension slots require further development in that they need to be populated with instances. The architecture of the ontology would likely be impacted by small changes to definitions, eg, Purpose, and therefore has high sensitivity. This is not necessarily a negative outcome and the evaluation criteria of sensitivity seems unnecessary for this ontology.

6.5 Usefulness of the Ontology

The Competency questions in 5.6 show some of the types of queries the intended audience might use to search the ontology. Queries can be used to gather information from the ontology, making it useful to clinical auditing communities, quality indicator developers, organisers of quality indicator sets and providers of access to quality indicator sets to reduce effort involved in healthcare quality monitoring. Clinical auditing communities, organisers of quality indicator sets and providers of access to quality indicator sets can search for quality indicators with common criteria, even if they are from

different sources. Auditing communities may therefore be able to gather or extract data for common criteria, rather than gathering the data separately for each indicator. Query writers for indicators, including those working for vendors of electronic health records, may store components of queries for common criteria and build queries for specific indicators out of common components, specifying additional components as necessary. Quality indicator developers may learn from the ontology by noting areas that could be simplified through more easily accessible and/or clearer metadata. The indicator developers could work towards modifying the indicators with a view towards a consistent metadata framework.

Experts and stakeholders were contacted to comment on the ontology. While one NHS stakeholder said his job was more about responding to outcomes than the quality monitoring process, another NHS stakeholder suggested that the ontology could reduce time needed to find relevant components of quality indicators and recommended that the ontology be patented. The most common view among academic experts was that the ontology could be a useful tool for finding relevant quality indicators and indicator components. Two EHR vendors have expressed interest in the ontology.

6.6 Limitations

This study was limited by unpredictable changes in the indicators and indicator subsets, lack of previous experience in ontology development, lack of medical expertise, lack of previous experience in clinical coding and poor quality metadata about the indicators. The Conceptualisation and

Formalisation stages were labour-intensive, due to the large, diverse nature of this set of quality indicators and poor standard of metadata readily available for the indicator set. The NHS Information Centre for Health and Social Care (NHS IC) was the primary source for metadata for instances of the indicators, as it was the site of access to the set of indicators used for this project.

Changes in the indicators and indicator sets could become more predictable through lessons learned from this study and through research into patterns in indicator development. Lack of expertise and experience can be addressed through collaborative studies. Preparatory studies, involving data availability in EHRs, could help to inform the conceptualisation process for the development of computer-interpretable healthcare quality indicators. However, there is room for debate as to whether data for all healthcare quality indicators should be made available through electronic health records. It has been suggested that Patient Experience scores are less likely to be maintained as part of an electronic health record (Roth et al. 2009).

6.7 Summary

This chapter has considered the results of the research, including the ontology development process and evaluation of the ontology itself. The methodology and platform chosen to develop the ontology were reviewed, with their respect to their usefulness to this project. Comments were made on the evaluation methods and results. Limitations of the study were discussed. The next chapter will review the contribution this research has made, the

research objectives and make suggestions for future healthcare quality indicator ontology development.

Chapter 7 Conclusions

This chapter describes the contributions to research made by this project. Section 7.1 offers a reminder of research gaps in the area of computer-interpretable quality indicators and ontologies for healthcare quality indicators and shows how this research has responded to those gaps. The hypothesis and objectives of this research are reviewed in 7.2, followed by a recap of the benefit of this ontology to clinical auditing communities, quality indicator developers and EHR vendors. Conclusions are drawn for each of the review items.

7.1 Research Contributions

This project sought to reduce duplication of effort in finding data for NHS healthcare quality indicators, to resolve issues identified in previous efforts to develop quality-monitoring ontologies or computer-interpretable quality indicators, to explore attributes of and relationships between healthcare quality indicators, and to identify areas for future computer-interpretable quality indicator development for the United Kingdom's Department of Health and National Health Service. This research is timely and potentially responds, in part, to a recent call for tools to support effective and efficient data collections (Informatics Services Commissioning Group 2013).

As previously identified in the literature review, 2.6.3.5, Challenges for Computer-Interpretable Quality Indicators, and discussion, 6.1, Purpose of Research and Choice of Indicator Set, the gaps in previous research in this area included classification of healthcare quality indicator purposes over a broad range of indicators, an ontology for healthcare quality indicators that is not dependent on data available in EHRs, a healthcare quality indicator ontology that covers many clinical subject areas, and a healthcare quality indicator ontology that does not require indicator developers to fit into framework. Being dependent on data available in EHRs led to difficulties using Arden Syntax to express inclusion and exclusion criteria (Jenders 2008). As well as being data-dependent, Arden Syntax, which was used to express a set of indicators for elderly care (Jenders 2008) may be limited to the purpose of screening and prevention (Ohno-Machado et al. 1998). Arden Syntax (Jenders 2008) and Surján's (et al. 2006) ontology for Public Health Indicators were applied to a subject-specific indicator set. The US Quality Data Model (2008) requires indicator developers to fit into a specified framework. Chan et al. (2010) advocate for research into attributes of quality indicators to support electronic health record compatibility. This research resulted in an ontology that is not dependent upon data available in EHRs, is not subject-specific, and does not require indicator developers to fit into a specified framework.

A review of research into computer-interpretable guidelines (Sonnenberg and Hagerty 2006) identified knowledge-centric, document-centric and hybrid approaches to guideline modelling. This description of approaches can also be applied to development of computer-interpretable quality indicators. The

knowledge-centric approach requires taking software compatibility into consideration and may be compared to the US Quality Data Model requiring developers to use a framework. The document-centric approach views the original indicator as the information base. The information is then reformatted, for example into elements, and tagged to work with related software. The research for this thesis took a document-centric approach, classifying metadata and representing the quality indicators with Protégé 3.4.1. The hybrid approach would seek a compromise between the knowledge-centric and document-centric approaches, perhaps asking indicator developers to uniformly develop certain components of the indicators.

7.2 Review of Hypothesis and Research Objectives

The research hypothesis and objectives were developed to address some of the research gaps discovered during the literature review.

7.2.1 Hypothesis

The hypothesis of this research was that the conceptualisation stage of ontology development for a large set of health care quality indicators can facilitate specification of inclusion and exclusion criteria, along with categorisation beyond screening and prevention and identification of levels of indicator relationships. The hypothesis was correct, with the limitation that availability, accessibility, complexity and accuracy of relevant metadata has a major influence on conceptualisation and formalisation.

Stated as two research questions, the hypothesis translated to:

1) What attributes of health care quality indicators influence the development of an ontology that emphasises specification of inclusion and exclusion criteria, along with specification beyond screening and prevention?
2) What relationships between health care quality indicators identify complexity of indicator relationships?

The attributes for inclusion and exclusion criteria and specification beyond screening and prevention are explored in Appendix 5, Layers of Inclusion/Exclusion Criteria and in Appendix 4, Indicators by Purpose, with Related Indicators. Concluding statements about the attributes are in 7.2.2.1, Attributes Suited to Ontology Coverage. Complexity of indicator relationships is discussed in 7.2.2.2, Relationships, Inclusion and Exclusion Criteria.

7.2.2 Research Objectives

The conceptualisation process achieved the first of the research objectives and partially achieved the second and third objectives. The research objectives were:

1) To identify relationships in a large, diverse set of quality indicators
2) To identify layers of inclusion and exclusion criteria for a large, diverse set of quality indicators
3) To determine the attributes of quality indicators most suited to ontology coverage
4) To determine whether there any features of quality indicators that do not need an ontology to facilitate quality-monitoring
5) To develop a preliminary ontology for a large, diverse set of quality indicators

7.2.2.1 Attributes Suited to Ontology Coverage

Attributes most suited to ontology coverage were determined during the conceptualisation process by deciding the classes and subclasses and their assigned slots and subslots. Some of the attributes, such as Next Stage Review Pathway, are specific to NHS quality indicators. It would be worth exploring the National Quality Forum's Data Model (2012b) to determine whether any of their data elements would fit into a future version of this ontology. Consultation with stakeholders may further assist with assessment of quality indicator attributes most suited to ontology coverage.

By analysing a diverse set of quality indicators, we have seen that not all indicators are fractional in nature. Patient Experience indicators tend to use a scale rating system, rather than numerator and denominator. Determining layers of inclusion criteria presented a challenge for some Patient Experience indicators, due to an awareness that the data for these types of indicators would likely involve numbers tallied from surveys, rather than queries written for electronic health records or other reporting systems. Some fractional indicators include defining criteria for components of the indicators. Incorporating definitions into layers of inclusion and exclusion criteria could be attempted by increasing numbers of layers of the criteria or by creating look-up tables.

The evaluation of the ontology showed that while the Safety class and Dimension subclasses have slots, they currently have no Instances and

therefore their Slots appear to have no use. The Dimension slots of Complication Rates, Mortality Rates, Patient-Reported Outcome Measures, Survival Rates, Compassion, Dignity, Respect, Cleanliness, Drug Errors, and Healthcare-related Infections, could be useful to clinical audit communities searching the ontology for related indicators. Future versions of this ontology should include instances of the indicators for each of these slots.

7.2.2.2 Relationships, Inclusion and Exclusion Criteria

Broader, narrower and same level indicators are specified in Appendix 4, Indicators by Purpose, with Related Indicators. Appendix 5 shows an initial set of layers of inclusion/exclusion criteria for each indicator. Variations in complexity of the indicator formulae and inconsistent and incomplete metadata regarding the formulae somewhat interfered with the fulfillment of the inclusion/exclusion criteria objective during the conceptualisation process. This research showed that healthcare quality indicators can be complex and are not necessarily "Simplistic algorithms that provide clear scoring instructions for processes that can be measured practically" (Walter 2004). Some of the indicators were not algorithms (eg, Patient Experience). Many of the indicators were complex, involving definitions and methods applicable to a portion of the indicator. Indicator complexity supports the decision to break down indicator components into inclusion and exclusion criteria.

There is potential for further specification of layers of inclusion/exclusion criteria, incorporating elements from metadata outside the indicator Statement. The NHS HSCIC metadata for Definition sometimes included

information that could be incorporated into inclusion/exclusion criteria. Some metadata from the NHS HSCIC's Formula/Calculation/Methodology or Detailed Descriptor sections could also be incorporated. The information given in these sections could not always be incorporated directly, as it often included non-formulaic detail or formulaic detail that included unfamiliar computer programming language terms. The addition of look-up tables for definitions and relevant computer programming terms could facilitate interoperability between different monitoring systems.

7.2.2.3 Specification Beyond Screening and Prevention

One of the objectives of this research was to determine whether a diverse set of healthcare quality indicators shared a common purpose of screening and prevention. This research showed that the most common purpose was Care of Clinical Conditions, thus suggesting that Arden Syntax may be inadequate to express different types of indicators. While this contention was originally made regarding the use of Arden Syntax to express CPGs, it would be prudent to test Arden Syntax directly on indicators with different purposes, along with indicators with multiple levels of inclusion or exclusion criteria. The Medical Logic Modules used in Arden Syntax historically have relied on singular criteria: one set of data for input, one application of criteria logic and one set of resulting actions. It is worth considering whether simple quality indicators, rather than just those with a purpose of screening and prevention, may be suitable for Arden Syntax.

IoM guideline purposes were selected to categorise the indicators because they were used to describe the suitability of Arden Syntax for representing clinical guidelines. There are just five IoM purposes (Field and Lohr 1992): 1) Screening and Prevention, 2) Diagnosis and prediagnosis management of patients, 3) Indications for use of surgical procedures, 4) Appropriate use of specific technologies and tests as part of clinical care, and 5) Guidelines for care of clinical conditions. The IoM categories represent both broad and narrow aspects of healthcare purposes. Broad and narrow categories for healthcare quality indicators are advisable to provide an overview of the spread of areas of healthcare addressed by quality indicators. Five categories may be too limited to adequately describe quality indicator purpose, however. Clinical guidelines have now progressed to organisation by a greater number of purposes. Some of these new categories are worth considering for healthcare quality indicators, bearing in mind that quality indicators are frequently derived from clinical guidelines (Mertz 2009, Kotter 2012). Categorisation by a larger range of purposes, such as the purposes developed by the US National Guideline Clearinghouse (Agency for Healthcare Research and Quality [2012]) and the US National Quality Forum (2012b) may facilitate a more useful and meaningful classification.

7.2.2.4 Features of Quality Indicators that Do Not Need an Ontology to Facilitate Healthcare Quality Monitoring

The fourth objective, to determine whether there are any features of quality indicators that do not need an ontology to facilitate healthcare quality monitoring, may be addressed, at least in part, by the difficulty encountered

with integrating indicator formulae into this ontology. Improved metadata for formulae and look-up tables for different layers of inclusion/exclusion criteria may be able to solve this problem in the future. Testing the ontology with end users may also help to determine features of quality indicators that do not need an ontology to facilitate healthcare quality monitoring.

7.2.2.5 A Preliminary Ontology

The conceptualisation stage facilitated the final objective, to develop a preliminary ontology for a large, diverse set of quality indicators. The use of Protégé 3.4.1 to create the ontology resulted in some slots/widgets being intentionally primitive, allowing the user to enter more than one data type. This flexibility is sometimes considered necessary to accurately identify the information and make it both searchable and linked. For example, Clinical Terminology entries include both code(s) and term(s). The complete terminologies used would need to be integrated into the ontology, with a look-up feature if the slot did not allow for more than one data type. The terminologies were browsed via UMLS, which requires registration. There may be licensing requirements for some of the terminologies to be used separately from UMLS. Data validation rules were kept intentionally broad, due to inconsistent and incomplete metadata supplied by the NHS IC.

7.3 Benefits of the Ontology

While a goal of interoperability between quality indicators and electronic health records (EHRs) is desirable, this conceptualisation process focused on the indicators themselves. This type of research and the resulting ontology

could be useful to countries in early stages of EHR implementation or that have not yet begun using EHRs. Countries that have already implemented EHRs, but recognise challenges in quality of data extraction from EHRs, may also be interested in this approach. The benefit is the ability to search for components of quality indicators from different sources, with a view to reducing duplication of effort in gathering data for indicators with common criteria, whether that data is gathered manually or electronically. EHR vendors could also learn from this ontology and work towards making indicator elements available in EHRs.

Queries can be used to gather information from the ontology, making it useful to clinical auditing communities, quality indicator developers, organisers of quality indicator sets and providers of access to quality indicator sets to reduce effort involved in healthcare quality monitoring. The target audience can search for quality indicators with common criteria, even if they are from different sources. Clinical auditing communities may therefore be able to gather or extract data for common criteria, rather than gathering the data separately for each indicator. Query writers for indicators, including those working for vendors of electronic health records, may store components of queries for common criteria and build queries for specific indicators out of common components, specifying additional components as necessary. Quality indicator developers may learn from the ontology by noting areas that could be simplified through more easily accessible and/or clearer metadata. The indicator developers could work towards modifying the indicators with a view towards a consistent metadata framework.

7.4 Summary

This chapter has described the contributions to research made by this project. The hypothesis and objectives of this research were reviewed. The conceptual analysis of this set of indicators serves as a snapshot into indicator status, categories and relationships. Categories of dimension, clinical pathway and purpose were identified as attributes of the indicators, along with broader, narrower and same level relationships between indicators from different sources and sets. The benefit is the ability to search components of quality indicators from different sources, with a view to reducing duplication of effort in gathering data for indicators with common criteria.

This study made the following research contributions:

1) Identified broader, narrower and same level criteria from different sets of NHS quality indicators,
2) Developed an initial set of inclusion and exclusion criteria for a large, diverse set of NHS quality indicators,
3) Reviewed literature on the use of ontologies for health care quality monitoring via electronic health records,
4) Noted challenges in the development and use of metadata for NHS healthcare quality indicators,
5) Compared broad purposes of a large, diverse set of NHS quality indicators.

The next chapter will make recommendations for the development of metadata for future healthcare quality indicator sets and future healthcare quality indicator ontology development.

Chapter 8 Considerations for future healthcare quality indicator ontology development

This chapter proposes recommendations for the development of metadata for future NHS healthcare quality indicator sets. Suggestions for future NHS healthcare quality indicator ontology development are proposed, including interoperability with electronic health records and clinical practice guidelines.

8.1 Indicator Metadata Readiness

Future work should consider authority records for associated creators, publishers and relevant parties responsible for indicator content and distribution. Authority records would enable users of metadata to find the most appropriate name and history of name changes associated with parties responsible for indicator content and access. The International Federation of Library Association's (2009) Statement of International Cataloguing Principles could be used as a starting point to develop standards for metadata for quality indicators. A companion guide to these principles, Resource Description and Access has been made available by the Joint Steering Committee for Development of RDA (2009).

8.2 Potential to Integrate with EHRs

Standards for information technology for decision support and quality monitoring have been criticised (Kawamoto et al. 2010) as being overly complex, having tooling limitations, and poor documentation on how the standards should be implemented. Feasibility of quality monitoring via EHRs

has been questioned by Jensen (2009), who showed that a majority of EHR systems did not have the capability to capture data for complex EHR-based measures, for example data elements based on workflow actions. Application of computer-interpretable quality indicators can be hampered by lack of available data in electronic health records (Roth et al. 2009). While the NHS has published standards for electronic health records (Academy of Royal Medical Colleges/NHS 2008), there is room for improvement with respect to coordinating these standards with conceptual elements of NHS quality indicators.

While this ontology bypasses the need for data provided via EHRs, it is recognised that EHR compatibility is a desirable feature of computer-interpretable quality indicators. Some of Kelly's (2012) advice for predictive modelling could support interoperability between EHRs and computer-interpretable quality indicators. The following summary of Kelly's Technical Guidance for Data Sources could be used to create look-up tables to incorporate into this pilot ontology, with potential links to EHRs:

> "1. Create and maintain a comprehensive data dictionary for all data sources.
> 2. Create an ER data model for all data sources.
> 3. Document data formats for all data sources.
> 4. Document data transport methods for all data sources.
> When selecting a predictive model:
> 1. Ask which types of data (IP, OP, GP etc.) were used within the training dataset.
> 2. Ask which data sources were used (e.g. SUS) for the training dataset.
> 3. Ask when the data was extracted for the training set.
> 4. Ask the scope of the data in the training dataset, specifically the historical scope (for example 4 years of data) and boundary scope (for example all GP registered patients in CCG X)."

Although this summary pertains to predictive models and mentions training datasets, there are commonalities between quality indicators and the types of information likely to be included in this training set. SUS, or Secondary Uses Service is a repository for healthcare reporting data in England. The training dataset referred to in Kelly's summary could be used to see how well it works with the pilot ontology developed for this research and to determine additional slots.

The National Quality Forum (2012c) has published a style guide, intended to assist quality indicator developers with feasibility requirements for data elements in proposed quality indicators. The style guide was inspired by a 2008 Information Technology Panel Report (National Quality Forum) that analysed quality indicator element availability in EHRs and made recommendations regarding quality indicator elements. There are ongoing issues regarding the NQF indicator sets, including duplication of value sets or components of value sets (Winnenburg and Bodenreider 2012). Efforts to integrate healthcare quality monitoring with EHRs are largely dependant on the quality of the data in the EHRs. According to the NHS Information Centre (2012b), there is much room for improvement in the quality of data available in EHRs in England, drawing into question current viability of quality monitoring via EHRs in England.

8.3 Integration of Quality Indicators with Clinical Decision Support

The National Quality Forum (2010) is also working to integrate quality monitoring with clinical decision support. Reporting structures are more complex for quality indicators than for CPGs, which are largely intended for local use, though sometimes may be monitored by public bodies. Advani et al. (2003) created quality indicators from clinical practice guidelines, using QUIL (Quality Indicator Language). Future quality indicator sets could more closely tie clinical practice guidelines with their relevant quality indicators, applying technologies such as QUIL.

8.4 Summary of Considerations for Future Healthcare Quality Indicator Ontology Development

This chapter has offered considerations for future healthcare quality indicator development, including metadata readiness, potential integration with EHRs and integration with clinical decision support. While this research focused on a set of quality indicators, future research could emphasise interoperability. The addition of look-up tables for authority records, indicator definitions, EHR standards and relevant computer programming terms could facilitate interoperability between different monitoring systems. Future quality indicator sets could more closely tie clinical practice guidelines with their relevant quality indicators, applying technologies such as QUIL. Categorisation by a larger range of purposes may also facilitate closer ties to CPGs.

Searchability was an important benefit of this ontology. Look-up tables could facilitate clearer data elements for inclusion and exclusion criteria. The number and usefulness of slots should be reviewed. Testing a range of simple quality indicators, rather than just those with a purpose of screening and

prevention, with Arden Syntax could further validate the need for an ontology designed for healthcare quality indiators. Further testing of the ontology with end users, with the support of a relevant NHS body, could help improve the ontology as well as publicise its usefulness.

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Appendix 1: MeSH Tree Structure for ‘Quality of Health Care’

(National Library of Medicine 1998)

This appendix shows the US National Library of Medicine Medical Subject Headings Tree Structure for ‘Quality of Health Care’. The hierarchical Tree Structure has branches stemming from sixteen categories. This helps to conceptualise different aspects of healthcare quality, with narrower and same level components. ‘Clinical Practice Guidelines’ and ‘Quality Indicators, Health Care’ are two related aspects of healthcare quality.

All MeSH Categories

Health Care Category

Health Services Administration

Quality of Health Care

Advance Directive Adherence

Clinical Competence

Guideline Adherence

Outcome and Process Assessment (Health Care)

Outcome Assessment (Health Care) +

Process Assessment (Health Care)

Peer Review, Health Care

Professional Review Organizations

Program Evaluation

Benchmarking

Quality Assurance, Health Care

Benchmarking

Clinical Audit +

Guidelines as Topic +

Laboratory Proficiency Testing

Total **Quality** Management

Quality Improvement

Quality Indicators, Health Care

Risk Adjustment

Standard of Care

Utilization Review

Concurrent Review

Drug Utilization Review

All MeSH Categories

Health Care Category

Health Care **Quality**, Access, and Evaluation

Quality of Health Care

Epidemiologic Factors

Age Factors +

Bias (Epidemiology) +

Causality +

Comorbidity

Confounding Factors (Epidemiology)

Effect Modifier, Epidemiologic +

Reproductive History

Sex Factors

Health Care Evaluation Mechanisms

Advance Directive Adherence

Data Collection +

Epidemiologic Research Design +

Epidemiologic Study Characteristics as Topic +

Evaluation Studies as Topic +

Guideline Adherence

Organizational Case Studies

Outcome and Process Assessment (Health Care) +

Patient Satisfaction

Program Evaluation +

Root Cause Analysis

Statistics as Topic +

Technology Assessment, Biomedical

Peer Review, Health Care

Standard of Care

Appendix 2: NHS Information Centre Metadata Headings List

(NHS Information Centre 2009b)

This appendix shows the NHS Health and Social Care Information Centre (NHS HSCIC) Metadata Headings list, used to inspire the Glossary of Terms and the starting point for conceptualisation. As the list of indicators was supplied by the NHS HSCIC, it was appropriate to consider the metadata headings used to describe the indicators by the NHS HSCIC for the glossary of terms. Definitions for the NHS HSCIC's Metadata Headings list are available from the NHS Information Centre. (2009b) Indicator Metadata Library Guide, along with clarifying information such as purpose and examples.

The headings selected from the NHS HSCIC were: Library Reference Number/Identifier (renamed 'Unique Identifier' as this metadata should not be duplicated), Source (renamed 'Reference' as 'Source' is ambiguous), Title (renamed 'Statement' as Titles are generally not duplicated in other types of metadata and in library catalogues), Calculation/Methodology/ Formula (renamed 'Formula' and used in a narrower context), URL (this is a modification of the NHS HSCIC's 'Accessibility' heading, which refers to potentially unlimited published information relating to the indicator), Publisher, Version (renamed 'Version History'), Other Related PI's (renamed relations) and Notes (with a slightly different definition).

Library Reference Number / Identifier
Subject
Category
Title

Detailed Descriptor
Rationale
Definition
Units
Coverage
Source
Calculations/Formula/Methodology
Creator
Status
Quality
Date
Version History
Update Frequency
Accessibility
Publisher
Other related PI's (Relation)
Additional Information
User Feedback

Appendix 3: Quality Indicator Dimensions and Next Stage Review Pathways

The Dimensions are: Effectiveness, Safety and Experience.

The Pathways are: Acute Care, Children's Health, End of Life Care, Learning Disabilities, Long Term Conditions, Maternity and Newborn, Mental Health, Other, Planned Care and Staying Healthy.

The column, Indicator Set or Creators, lists the information used to fill in the Reference slot in the ontology. The information for this slot was taken from the NHS IC Source metadata. Sometimes there is more than one party responsible for the development of the indicator. This is the reason for including alternate information in the third column.

Prior to entering instances, a Snapshot rule was created to address different status levels of the indicators. If an indicator had a status of ***Dropped*** at the time of recording data into the table, the instance was not entered into the ontology. If an indicator had a status of ***Dropped*** after it was recorded into the table, the indicator was entered as an instance into the ontology. If an indicator had a status of ***Replaced by***, at the time of recording into the table, the indicator was not entered into the ontology. If an indicator had a status of ***Replaced by*** after recording the indicator into this table, it was entered into the ontology. Relationships and sometimes URL are not given if the indicator is no longer in use.

Dimension	Next Stage Review Pathway (NSR)	Indicator Set(s) and/or creators	URL closest to methodology	Number of Indicators
Effectiveness	Acute Care	Myocardial Ischaemia National Audit Project (RCP)	http://www.hqip.org.uk/myocardial-ischaemia-national-audit-project-minap/ [Link to RCP project site is broken]	3 (CV34, CV35, CV36)
	Acute Care	Compendium of Public Health Indicators/National Centre for Health Outcomes Development (funded by NHS IC) for Numerator. Hospital Episode Statistics for Denominator	https://indicators.ic.nhs.uk/webview/ [frames-based – must click on links within website]	5 (RA01, RA18, RA20, RA24)
	Acute Care	Commissioning Data Sets, 12 Months	http://www.nhs.uk/Scorecard/Pages/IndicatorFacts.aspx?MetricId=6&OrgType=5	3 (RA17, RA25 (no longer in use), RA26)
	Acute Care	Department of Health Vital Signs – Tier 1	http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_082542	1 (CV10)
	Acute Care	National Sentinel Stroke Audit [CV01, CV02 and CV06 are also CQC indicators] (RCP)	https://mqi.ic.nhs.uk/documents/ Stroke Clinical Proforma 2008 REVISED.doc [Links to RCP are broken]	6 (CV01, CV02, CV06, CV13, CV14, CV20)
	Acute Care	Surgical Site Infection Surveillance Service (Health Protection Agency) NICE may be original source	http://www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/SurgicalSiteInfection/Guidelines/	1 (HC24)

Dimension	NSR Pathway	Indicator Set(s) and /or creators	URL closest to methodology	Number of Indicators
	Childrens' Health	Immunisation Team, NHS Information Centre? [May be Health Protection Agency]	[Refers to a chapter with incomplete citation and no URL] Source for this table: https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.02.02	3 (WCC 2.09, WCC 2.10, WCC 2.11)
	Childrens' Health	Child and Adolescent Mental Health Service	[No longer collected by Dept of Health as no longer in Vital Signs performance measure]	2 (CF01, CF02) [No longer in use]
	End of Life Care	Quality and Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	2 (QOF PC 2, QOF PC 3)
	End of Life Care	National Centre for Health Outcomes Development Compendium indicators, World Class Commissioning	http://www.nchod.nhs.uk/NCHOD/Compendium.nsf/17b8958892856d44802573a30020fcd9/37353698180d191d6525751a00363101!OpenDocument	1(WCC 3.24)
	Learning Disabilities	Quality and Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	1 (QOF LD 1)
	Long Term Conditions	Quality and Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx, Also associated with Dept of Health. Data available via NHS Information Centre.	15 (QOF AF 4, QOF AF 1, QOF AF 3, QOF CANCER 3, QOF CANCER 1, QOF CHD 1, QOF CHD 2, QOF CHD 5, QOF CKD 2, QOF CKD 1, QOF CKD 3, QOF CKD 5, QOF HF1, QOF BP 1, QOF STROKE 1)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Long Term Conditions	Cancer Policy Team, Department of Health	http://transparency.dh.gov.uk/cancer-waiting-times/	6 (CWT 1, VSA08, VSA11a, VSA12, VSA13, VSA11b)
	Long Term Conditions	NHS Cancer Screening Programmes / NHS Information Centre [WCC 2.23 is also an indicator for NHS Choices and the Care Quality Comission, WCC 2.25 is/was associated with the Care Quality Comission	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.05.07 [URL given on this page does not work] http://www.connectingforhealth.nhs.uk/systemsandservices/ssd/downloads/cytology/contents/kc53 [for WCC 2.23]	5 (VSA09, VSA10, VSA15, WCC 2.23, WCC 2.25- no longer in use)
	Long Term Care	Myocardial Ischaemia National Audit Project	http://www.hqip.org.uk/myocardial-ischaemia-national-audit-project-minap/ [Link to RCP project site is broken]	1 (CV47)
	Long Term Care	National Clinical Audit Support Programme (NCASP)/RCP. CV37 is also an indicator for CQC England	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.05.27 [No other link given on IC site for CV37 & 38, RCP link for CV09 is broken]	3 (CV37, CV38, CV09)
	Long Term Care	National Sentinel Stroke Audit	https://mqi.ic.nhs.uk/documents/ Stroke Clinical Proforma 2008 REVISED.doc [Links to RCP are broken]	2 (CV16 -no longer in use, CV21 - not in public domain)
	Long Term Care	National Bowel Cancer Audit. CA40 has been incorporated into a NICE guideline	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.05.32 [No other URL given]	2 (CA36 – no longer produced, CA40)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Long Term Care	National Lung Cancer Audit	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.05.34 [No other URL given]	1 (CA41)
	Long Term Care	UK Renal Registry	http://www.renalreg.com	10 (LT13, LT14a, LT14b, LT15, LT17, LT18, LT20a, LT20b, LT21, LT22)
	Maternity and Newborn	DoH Vital Signs National Priority Tier 2 and NICE. Health Improvement Analytical Team, DH specified as Creator/Producer for VSB11. Info Ctr specified as Creator/Producer for VSB06	https://mqi.ic.nhs.uk/ IndicatorDefaultView.aspx?ref= 1.06.01 [URL given does not work]	2 (VSB06 – related to Na'tl Indicator Set: NI 126, VSB11)
	Maternity and Newborn	Care Quality Commission	[URL given defaults to CQC homepage: http://www.cqc.org.uk/public	1 (WCC2.06)
	Mental Health	Quality and Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/ QualityOutcomesFramework.aspx	10 (QOF DEM 2, QOF DEM 1, QOF DEP 2, QOF DEP 1, QOF MH 9, QOF MH 4, QOF MH 6, QOF MH 7, QOF MH 8, QOF MH 5)
	Mental Health	DoH, Improving Access to Psychological Therapies. Associated with NICE.	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.07.12 [IAPT URL given is broken, though can still access general IAPT site]	1 ([QOF] MH 12 - Related to Vital Signs Indicator Tier 3 Improve Access to Psychological Therapies , PSA 18 Indicator 5 : Improve Access to Psychological Therapies)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Other [Organ Donation]	Potential Donor Audit, NHS Blood and Transplant (NHSBT)	http://www.bmj.com/content/332/7550/1124.full?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=Barber+K&fulltext=donation&andorexactfulltext=and&searchid=1&FIRSTINDEX=0&sortspec=relevance&resourcetype=HWCIT	4 (LT25, LT26, LT27, LT24)
	Planned Care	Cancer Quality Information Network System. CA45 is/was also associated with NICE	https://mqi.ic.nhs.uk/Search.aspx?query=CA27&ref=1.09.01.01 [Other URLs given do not work]	6 (CA27, CA28, CA45 – these measures have been dropped, CA29, CA51, CA01 – still in use)
	Planned Care	National Bowel Cancer Audit	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.05.34 [No other URL given]	1 (CA42a – no longer in use)
	Planned Care	National Head and Neck Cancer Audit. Associated with National Clinical Audit Support Programme	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.09.01.08 [No other URL given]	1 (CA42b) [This has been replaced by another indicator, with different descriptive information]
	Planned Care [Extra column labelled 'Topic' = Cancer	National Lung Cancer Audit	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.09.01.09 [No other URL given]	1 (CA42c)
	Planned Care [Extra column labelled 'Topic' = Cardiovascular]	Quality Outcomes Framework QOF PP 1 associated with NICE CG 67.	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	14 (QOF CHD 6, QOF CHD 7, QOF CHD 8, QOF CHD 9, QOF CHD 10, QOF CHD 11, QOF CHD 12, QOF HF 2, QOF HF 3, QOF HF 4, QOF BP 4, QOF BP 5, QOF PP1, QOF PP 2 – described as 'Future Indicator' with anticipated date)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Planned Care [Extra column labelled 'Topic' = Cardiovascular]	Central Cardiac Audit Database from National Clinical Audit Support Programme. Associated with Care Quality Commission and now under the National Institute for Cardiovascular Outcome Research.	http://www.ucl.ac.uk/nicor/audits http://heartsurgery.cqc.org.uk/about-aortic-valve.aspx (CV49)	3 (CV48, CV49, CV52 – described as 'Future Indicator')
	Planned Care [Extra column labelled 'Topic' = Cardiovascular]	Myocardial Ischaemia National Audit Project	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.09.02.17 [Royal College of Physicians links are broken]	5 (CV29, CV30, CV31, CV32, CV33)
	Planned Care [Extra column labelled 'Topic' = COPD]	Quality Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx [QOF COPD 13 associated with NICE CG12 and CCQ]	6 (QOF COPD 12, QOF, COPD 10, QOF COPD 1, QOF COPD 8, QOF COPD 13 – described as 'Future Indicator' with anticipated date, QOF COPD 11 – no longer in use)
	Planned Care [Extra column labelled 'Topic' = Diabetes]	Quality Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	18 (QOF DM 21, QOF DM 7 – replaced by QOF DM 12, QOF DM 9, QOF DM 10, QOF DM 11, QOF DM 12, QOF DM 13, QOF DM 15, QOF DM 16, QOF DM 17, QOF DM 18, QOF DM 22, QOF DM 19, QOF DM 2, QOF DM 5, QOF DM 23, QOF DM 24, QOF DM 25 - designated as 'Future Indicator' with anticipated date)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Planned Care [Extra column labelled 'Topic' = Other]	Quality Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	10 (QOF ASTHMA 8, QOF ASTHMA 3, QOF ASTHMA 6, QOF ASTHMA 1, QOF EPILEPSY 6, QOF EPILEPSY 5, QOF EPILEPSY 7, QOF EPILEPSY 8, QOF THYROID 2, QOF THYROID 1,)
	Planned Care [Extra column labelled 'Topic' = Other]	Hospital Episode Statistics via British Association of Day Surgery	http://daysurgeryuk.net/bads/joomla/index.php/efficiency-assessment-tool	1 (TC05 – status unknown)
	Planned Care [Extra column labelled 'Topic' = Other]	Commissioning Data Sets_36 Months	http://www.nhs.uk/Scorecard/Pages/IndicatorFacts.aspx?MetricId=94&OrgType=5	2 (MR30, MR31)
	Planned Care [Extra column labelled 'Topic' = Other]	Department of Health	http://transparency.dh.gov.uk/2012/07/05/diagnostics-information/	1 (TC03)
	Planned Care [Extra column labelled 'Topic' = Other]	Quality Outcomes Framework QOF CKD 6 also associated with NICE CG 73 and SIGN 103	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	6 (QOF DEP 3, QOF CKD 6, QOF SH 1, QOF SH 2, QOF SH 3 – described as 'Future Indicator' with anticipated date)
	Planned Care [Extra column labelled 'Topic' = Other]	Hospital Episode Statistics	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.09.05.21 [No other URL given]	1 (HES 1 – described as 'Future Indicator' with no date)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Planned Care [Extra column labelled 'Topic' = Other]	Surgical Site Infection Surveillance Service (Health Protection Agency)	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=1.09.05.22 [Other URLs do not lead to methodology]	3 (HC22, HC23, HC25)
	Planned Care [Extra column labelled 'Topic' = Stroke]	Quality Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	7 (QOF STROKE 13, QOF STROKE 5, QOF STROKE 7, QOF STROKE 8, QOF STROKE 6, QOF STROKE 12, QOF STROKE 10)
	Planned Care [Extra column labelled 'Topic' = Stroke]	National Sentinel Stroke Audit (RCP) CV11 is also associated with DoH and VSA14, which is not part of this set	https://mqi.ic.nhs.uk/documents/Stroke%20Clinical%20Proforma%202008%20REVISED.doc and https://mqi.ic.nhs.uk/documents/2008%20Clinical%20audit%20help-booklet%20FINAL.doc	6 (CV03, CV08, CV05, CV11, CV19, CV04)
	Staying Healthy	Quality Outcomes Framework	http://www.nhsemployers.org/PayAndContracts/GeneralMedicalServicesContract/QOF/Pages/QualityOutcomesFramework.aspx	3 (QOF OB 1, QOF SMOKING 3, QOF SMOKING 4)
Patient Experience	Long Term Conditions	DoH	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=2.01.01	1 (VSC11)
	Long Term Conditions	Estates Returns Information Collection Data	http://www.hefs.ic.nhs.uk/	1 (ERIC1)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Long Term Conditions	Care Quality Commission Inpatient Services Survey. Related to Outpatients departments survey, Emergency Department Survey, Children and Young Peoples' Survey	http://www.cqc.org.uk/public [URL given by NHS IC defaults to general website] May be able to search for MQ39, Q32 (PE41), Q35 (PE42), Q36 (PE43, PE36 (Q47)) etc (ID numbers not always given), National Inpatient Survey 2011	15 (PE49, PE50, PE53, PE54, PE41, PE42, PE43, PE36, PE37, PE38, PE39, PE56, PE48, PE51, PE52 – status unknown for most or all of these indicators)
	Other	Patient Environment Action Team Assessment. National Patient Safety Agency, DoH, contracted with NHS IC. Data received by CQC and DoH	http://www.nrls.npsa.nhs.uk/patient-safety-data/peat/	3 (PEAT 1, PEAT 2, PEAT 3)
	Other	Patient Experience Headline Measures. DoH and CQC.	http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Publicationsandstatistics/PublishedSurvey/NationalsurveyofNHSpatients/DH_087516	8 (PEXIS1 – produced in part with data from PE04 & PE05, PEXIS2 – produced in part with data from PE23, PEXIS3 – produced in part with data from PE16, PE19 and PE20, PEXIS4 – produced in part with data from PE38, PE39 and PE42, PEXIS 5 – produced in part with data from PE09, PE36, PE37, PE48, PE49 and PE51, PEXIS6 no longer in use, PEXIS7 no longer in use, PEXIS8 – no longer in use)
	Other	Patient Survey Programme. CQC	http://www.cqc.org.uk/public [URL given on NHS IC site defaults to this general URL – may be able to search CQC site using Q38 on National Inpatient Survey]	1 (PE58)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Planned Care	Cancer Quality Improvement Network System	http://www.cquins.nhs.uk/ [more specific URL given is broken]	1 (CA25)
	Planned Care	CQC	http://www.cqc.org.uk/public [URL given on NHS IC site defaults to this general URL – may be able to search CQC site for PE07 using Q43, Q42 for PE15, Q41 for PE16, Q63 for PE18, Q64 for PE19, Q66 for PE21, Q67 for PE22, Q71 for PE26, Q77 for PE29, Q14 and 17 for PE33, Q19 for PE34, Q46 for PE35, Q30 for PE06, Q59 for PE17, Q49 for PE09, Q76 for PE28, Q65 for PE20, Q68 for PE23, Q69 for PE24, Q70 for PE25 on National Inpatient Survey 2011	25 (PE07, PE08, PE15, PE16, PE18, PE19, PE21, PE22, PE26, PE29, PE33, PE34, PE35, PE06, PE04, PE05, PE17, PE09, PE28, PE27, PE20, PE23, PE24, PE25, PE11 – no longer in use)
	Planned Care	Monthly diagnostic waiting times. DoH	http://transparency.dh.gov.uk/2012/07/03/monthly-diagnostics-data-2012-13/	1 (CV43)
	Planned Care	National Bowel Cancer Audit	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=2.03.28 [no other URL given]	1 (CA35a – based on NICE guideline (not specified)
	Planned Care	National Lung Cancer Audit	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=2.03.29 [no other URL]	1 (CA35b – NCLA [NLCA?] standard)
Safety	Planned Care	Health Protection Agency Infectious Diseases. DoH Vital Signs – Tier 1.	http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1233906819629	2 (PS37, PS39, VSA03)

Dimension	NSR Pathway	Indicator Set(s)	URL	Number of Indicators
	Planned Care	Surgical Site Infection Surveillance Service (Health Protection Agency)	http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1227774003731 [mostly data, with someuseful background detail]	1 (HC21)
	Planned Care	National Reporting and Learning System	https://mqi.ic.nhs.uk/documents/RLS%20CQI%20indicator%20defs.doc	3 (NRLS 1, NRLS 2, NRLS 3)
	Planned Care	National Staff Survey. CQC	http://www.cqc.org.uk/media [URL given defaults to CQC Media page]	1 (PS24)
	Mental Health	Mental Health Minimum DataSet, DoH, World Class Commissioning	https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=3.03.01 (MH06) https://mqi.ic.nhs.uk/IndicatorDefaultView.aspx?ref=3.03.03 (MH17)	3 (MH06, MH16, MH17)

Appendix 4. Indicators by Purpose, with Related Indicators

[referred to in referenced document as 'Guidelines', from Institute of Medicine 1992 classic CPG report (Field and Lohr 1992)]

The five purposes are:
"1) Screening and prevention: Eg, Vaccination for pregnant women who are planning international travel.
2) Diagnosis and prediagnosis management of patients: Eg, Evaluation of chest pain in the emergency room.
3) Indications for use of surgical procedures: Eg, Indications for carotid endarterectomy.
4) Appropriate use of specific technologies and tests as part of clinical care: Eg, Use of autologous or donor blood for transfusions.
5) Guidelines for care of clinical conditions: Eg, Management of patients following coronary-artery bypass graft"

Screening and Prevention	**Diagnosis and prediagnosis management of patients**	**Indications for use of surgical procedures**	**Appropriate use of specific technologies and tests as part of clinical care**	**Indicators for care of clinical conditions**
WCC 2.09 (Proportion of children completing MMR immunisation by 2nd birthday) **Narrower aspect to WCC 2.10**	CV02 (patients given a brain scan within 24 hours of stroke)	CV35 (patients who received primary angioplasty within 120 minutes of call)	CV20 (With the increasing use of thrombolysis in appropriate stroke patients this will enable national benchmarking of rollout)	CV34 (patients who received thrombolytic treatment within 60 minutes of call) **Broader than CV36**
WCC 2.10 (Proportion of children who complete MMR immunisation (1st and 2nd dose) by their 5th birthday) **Broader aspect to WCC 2.09**	CV06 (stroke patients given a swallow screening within 24 hours of admission)	CV36 (patients who received primary angioplasty within 120 minutes of call – **joint criteria with Indicators for Clinical Conditions**)	QOF CHD 5 (The percentage of patients with coronary heart disease whose notes have a record of blood pressure in the previous 15 months) **Narrower aspect to QOF CHD 1**	CV36 (patients who received thrombolytic treatment within 60 minutes of call **– joint criteria with Indications for Surgical Procedures**) **Narrower than CV34 and CV35**

Screening and Prevention	**Diagnosis and prediagnosis management of patients**	**Indications for use of surgical procedures**	**Appropriate use of specific technologies and tests as part of clinical care**	**Indicators for care of clinical conditions**
WCC 2.11 (Proportion of children who complete DTP immunisation by their 5th Birthday)	CV13 (Acute units with 5/6 key characteristics (… access to scanning within 3 hours of admission/24 hour brain imaging; policy for direct admission from A&E; …; acute stroke protocols/guidelines) – **joint criteria with Indicators for Clinical Conditions**)	VSA11a (Cancer 31-Day Subsequent Treatments Target (Surgery Treatments))	QOF CKD 2 (The percentage of patients on the CKD register whose notes have a record of blood pressure in the previous 15 months) **Narrower aspect to QOF CKD 1. Broader than CKD 3. Related to CKD 5.**	RA01, RA17, RA18, RA20, RA24, RA25, RA26 (Preventing readmissions by learning from other Trusts' data)

VSA09 (NHS Breast Screening Programme to women aged 53-70)	CV14 (access to scanning for patients with a stroke within 3 hours of admission**) Related to CV13 (same level)**	CA40 (Median number of lymph nodes examined in surgical specimen) **Related to CA41**	CA41 (Histological Confirmation Rate) **Related to CA40 (not essential to)**	CV13 (Acute units with 5/6 key characteristics (continuous physiological monitoring; access to scanning within 3 hours of admission/24 hour brain imaging; policy for direct admission from A&E; specialist ward round at least 5 times a week; acute stroke protocols/guidelines) – **joint criteria with Diagnoses Mgmt**) Related to CV14 (same level)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
VSA10 (Extension of NHS Bowel Cancer Screening Programme to men and women aged up to 75)	QOF AF 4 (The percentage of patients with atrial fibrillation diagnosed after 1 April 2009 with ECG or specialist confirmed diagnosis)	TC05 (Percentage of BADS (British Association of Day Surgery) Directory of Procedures (including electronic assessment) carried out as a day case or within appropriate length of stay)	QOF DEP 2 (In those patients with a new diagnosis of depression, recorded between the preceding 1 April to 31 March, the percentage of patients who have had an assessment of severity at the outset of treatment using an assessment tool validated for use in primary care) **Joint Criteria with Diagnosis**	CV01 (stroke patients given Aspirin or alternative e.g. clopidogrel within 48 hours of stroke)
VSA15 (All women to receive results of cervical screening tests within two weeks)	CWT 1 (patients first seen by a specialist within two weeks when urgently referred with suspected cancer)		QOF DEP 1 (The percentage of patients on the diabetes register and/or the CHD register for whom case finding for depression has been undertaken on one occasion during the previous 15 months using two standard screening questions) **Joint Criteria with Screening**	CV10 (High risk stroke unit patients are scanned and treated within 24 hours)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
WCC 2.23 (Proportion of women aged 25-49 and 50-64 screened for cervical cancer)	QOF CHD 2 (The percentage of patients with newly diagnosed angina (diagnosed after 1 April 2003) who are referred for exercise testing and/or specialist assessment)		QOF MH 4 (The percentage of patients on lithium therapy with a record of serum creatinine and TSH in the preceding 15 months)	HC24 (Rate of surgical site infection following open reduction of long bone fracture) **Narrower than HC21**
VSA08 (Breast Symptom Two Week Wait)	CV47 (Percentage of acute coronary syndrome patients who are seen by a cardiologist during admission.)		QOF MH 5 (The percentage of patients on lithium therapy with a record of lithium levels in the therapeutic range within the previous 6 months)	CF01, CF02 (Number of hospital occupied bed days on adult psychiatric wards of patients aged under 16, on admission, under the care of a psychiatric specialist) – **no longer in use**
QOF CKD 3 (The percentage of patients on the CKD register in whom the last blood pressure reading, measured in the previous 15 months, is 140/85 or less) **Narrower aspect to QOF CKD 1 & QOF CKD 2. Related to CKD 5.**	LT13 (Percentage of patients presenting to a nephrologist less than 90 days before RRT initiation.)		CA27 (Pathology services: percentage compliance with 3D measures)	QOF PC2 (The practice has regular (at least 3 monthly) multidisciplinary case review meetings where all patients on the palliative care register are discussed)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
CA36 (Percentage of bowel cancer cases where there is a histological report on the presence or absence of tumour in the resection margin)	QOF DEP 2 (In those patients with a new diagnosis of depression, recorded between the preceding 1 April to 31 March, percentage of patients who have had an assessment of severity at the outset of treatment…) **Joint Criteria with Appropriate Use**		CA28 (Imaging services: percentage compliance with 3B Measures)	QOF PC3 (The practice has a complete register available of all patients in need of palliative care/support irrespective of age)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
VSB06 (Percentage of women in the relevant PCT population who have seen a midwife or a maternity healthcare professional, for health and social care assessment of needs, risks and choices by 12 weeks and 6 days of pregnancy) **Narrower aspect to WCC 2.06**	QOF HF 2 (The percentage of patients with a diagnosis of heart failure (diagnosed after 1 April 2006) which has been confirmed by an echocardiogram or by specialist assessment) **Related to QOF HF 3 (same level**). **Broader than CV29, CV30, CV31, CV32, CV33. Joint Criteria with Appropriate Use**		CA29 (Radiotherapy: percentage compliance with 3E Measures)	WCC3.24 (Percentage of all deaths that occur at home)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
WCC 2.06 (Smoking during pregnancy) **Broader aspect to VSB06**	QOF BP 4 (The percentage of patients with hypertension in whom there is a record of the blood pressure in the previous 9 months) **Broader aspect to QOF BP 5, QOF PP1 and QOF PP2.**		QOF HF 2 (The percentage of patients with a diagnosis of heart failure (diagnosed after 1 April 2006) which has been confirmed by an echocardiogram or by specialist assessment) **Related to QOF HF 3 (same level). Joint Criteria with Diagnoses and Prediagnosis /Management**	QOF LD 1 (The practice can produce a register of patients with learning disabilities)
QOF DEP 1 (The percentage of patients on the diabetes register and/or the CHD register for whom case finding for depression has been undertaken on one occasion during the previous 15 months using two standard screening questions) **Joint Criteria with Appropriate Use**	CA42a (Percentage of [Bowel Cancer] cases reported to the audit with modified Dukes staging recorded)		QOF COPD 12 (The percentage of all patients with COPD diagnosed after 1st April 2009 in whom the diagnosis has been confirmed by post bronchodilator spirometry) **Joint criteria with Diagnoses/Prediagnoses Management.** **Narrower aspect to QOF COPD 1 and 13. Related to QOF COPD 8,10, 11 (same level).**	QOF AF 1 (The practice can produce a register of patients with atrial fibrillation) **Broader aspect to QOF AF 3**
	CA42b (Percentage of [Head and Neck Cancer] cases reported to the audit with pre-treatment T Stage and N Stage recorded)			
	CA42c (Percentage of patients reported to the audit that have stage recorded for their lung cancer)			

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
QOF CHD 6 (The percentage of patients with coronary heart disease in whom the last blood pressure reading (measured in the previous 15 months) is 150/90 **Narrower aspect to QOF CHD 7. Related to QOF CHD 8, QOF CHD 9, QOF CHD 10 and 12 (same level)**	QOF PP1 (In those patients with a new diagnosis of hypertension (excluding those with pre-existing CHD, diabetes, stroke and/or TIA) recorded between the preceding 1 April and 31 March: the percentage of patients who have had a face to face cardiovascular risk assessment at the outset of diagnosis (within three months of the initial diagnosis) using an agreed risk assessment treatment tool) **Related to QOF PP2 and QOF BP5 (same level). Narrower aspect to QOF BP 4**		QOF COPD 11 (**No longer in use**)(The percentage of patients with COPD receiving inhaled treatment in whom there is a record that inhaler technique has been checked in the previous 15 months) **Related to QOF COPD 8, 10, 12 Narrower aspect to QOF COPD 1, 13.**	QOF AF 3 (The percentage of patients with atrial fibrillation who are currently treated with anti-coagulation drug therapy or an anti-platelet therapy) **Narrower aspect to QOF AF 1**
QOF CHD 7 (The percentage of patients with coronary heart disease whose notes have a record of total cholesterol in the previous 15 months or less) **Broader aspect to QOF CHD 6, QOF CHD 8, QOF CHD 9. Related to QOF CHD 10 and 12 (same level)**	QOF COPD 12 (The percentage of all patients with COPD diagnosed after 1st April 2009 in whom the diagnosis has been confirmed by post bronchodilator spirometry) **Joint criteria with Diagnoses/Prediagnoses Management. Related to QOF COPD 8,10, 11 (same level). Narrower aspect to QOF COPD 1 and 13)**		QOF DM 9 (The percentage of patients with diabetes with a record of the presence or absence of peripheral pulses in the previous 15 months) **Related to QOF DM 2, 5, 7, 10, 11, 12, 13, 15, 16, 17, 18, 22, 19, 21, 22, 23, 24, 25 (same level)**	QOF CANCER 3 (patients with cancer, diagnosed within the last 18 months who have a patient review recorded as occurring within 6 months of the practice receiving confirmation of the diagnosis)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
QOF CHD 8 (The percentage of patients with coronary heart disease whose last measured total cholesterol (measured in the previous 15 months) is 5mmol/l or less) **Narrower aspect to QOF CHD 6, QOF CHD 7. Related to QOF CHD 9, QOF CHD 10 and QOF CHD 12 (same level)**	QOF DM 19 (The practice can produce a register of all patients aged 17 years and over with diabetes mellitus, which specifies whether the patient has Type 1 or Type 2 diabetes) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 21, 22, 23, 24 (same level)**		QOF DM 10 (The percentage of patients with diabetes with a record of neuropathy testing in the previous 15 months) **Related to QOF DM 2, 5, 7, 9, 11, 12, 15, 13, 16, 17, 18, 22, 19, 21, 23, 24, 25 (same level)**	QOF CANCER 1 (a register of patients with a diagnosis of cancer excluding non-melanotic skin cancers)
QOF CHD 12 (The percentage of patients with coronary heart disease who have a record of influenza immunisation in the preceding 1 September to 31 March) **Related to QOF CHD 6, QOF CHD 7, QOF CHD 8, QOF CHD 9, and QOF CHD 10 (same level)**	QOF DEP 3 (In those patients with a new diagnosis of depression and assessment of severity recorded between the preceding 1 April to 31 March, the percentage of patients who have had a further assessment of severity 5-12 weeks (inclusive) after the initial recording of the assessment of severity. Both assessments should be completed using an assessment tool validated for use in primary care)		QOF DM 11 (The percentage of patients with diabetes who have a record of the blood pressure in the previous 15 months) **Related to QOF DM 2, 5, 7. 9, 10, 12, 13, 15, 16, 18, 17, 22, 19, 21, 23, 24, 25**	VSA12 (Cancer 31-Day Subsequent Treatments Target (Radiotherapy))

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
QOF BP 5 (The percentage of patients with hypertension in whom the last blood pressure (measured in the previous 9 months) is 150/90 or less) **Narrower aspect to QOF BP 4. Related to QOF PP1 and QOF PP2.**	QOF STROKE 13 (The percentage of new patients with a stroke or TIA who have been referred for further Investigation) **Narrower aspect to QOF STROKE 1**		QOF DM 13 (The percentage of patients with diabetes who have a record of micro-albuminuria testing in the previous 15 months (exception reporting for patients with proteinuria)) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 15, 16, 17, 18, 22, 19, 21, 23, 24, 25 (same level)**	VSA13 (Extended 62-Day Cancer Treatment Targets)
QOF COPD 8 (The percentage of patients with COPD who have had influenza immunisation in the preceding 1 September to 31 March) **Narrower aspect to QOF COPD 1. Related to QOF COPD 10, 13, and 11**	CV05 (Proportion of stroke patients who see Physiotherapist within 72 hours of admission) **Narrower aspect to QOF STROKE 1**		QOF DM 22 (The percentage of patients with diabetes who have a record of estimated glomerular filtration rate (eGFR) or serum creatinine testing in the previous 15 months) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18 19, 21, 23, 24, 25 (same level)**	WCC 2.25 (Percentage of patients waiting no more than 31 days for cancer treatment) [Treatment not specific enough - could be surgery, radiotherapy or other]

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
QOF DM 21 (The percentage of patients with diabetes who have a record of retinal screening in the previous 15 months) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 22, 23, 24, 25 (same level)**	CV04 (Proportion of stroke patients who see occupational therapist within 4 working days) **Narrower aspect to QOF STROKE 1**		QOF DM 16 (The percentage of patients with diabetes who have a record of total cholesterol in the previous 15 months) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 17, 18, 19, 21, 22, 23, 24, 25 (same level)**	QOF CHD 1 (The practice can produce a register of patients with coronary heart disease) **Broader aspect to QOF CHD 5**
QOF DM 12 (The percentage of patients with diabetes in whom the last blood pressure reading is 145/85 or less) **Related to QOF DM 2, 5, 7, 9, 10, 11, 13, 16, 17, 18, 19, 21, 22, 23, 24, 25 (same level)**			QOF ASTHMA 8 (The percentage of patients aged eight and over diagnosed as having asthma from 1 April 2006 with measures of variability or reversibility) **Related to QOF ASTHMA 3, 6, 1 (same level, due to exclusion criteria in 1)**	QOF CKD 5 (The percentage of patients on the CKD register with hypertension and proteinuria who are treated with [appropriate medication]) **Narrower aspect to QOF CKD 1. Related to QOF CKD 2 & 3 (same level)**
QOF DM 17 (Percentage of patients with diabetes whose last measured total cholesterol within the previous 15 months is 5mmol/l or less) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 18, 19, 21, 22, 23, 24, 25 (same level)**			QOF THYROID 2 (The percentage of patients with hypothyroidism with thyroid function tests recorded in the previous 15 months) **Narrower aspect of QOF THYROID 1**	QOF HF 1 (The practice can produce a register of patients with heart failure)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
QOF DM 18 (The percentage of patients with diabetes who have had influenza immunisation in the preceding 1 September to 31 March) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 19, 21, 22, 23, 24, 25 (same level)**			QOF CKD 6 (The percentage of patients on the CKD register whose notes have a record of an albumin:creatinine ratio (or protein:creatinine ratio) test in the previous 15 months)	QOF BP 1 (The practice can produce a register of patients with established hypertension)
QOF STROKE 5 (The percentage of patients with TIA or stroke who have a record of blood pressure in the notes in the preceding 15 months) **Narrower aspect to QOF STROKE 1. Related to QOF STROKE 5 and 6.**			CV03 (Proportion of stroke patients given a Mood Assessment) **Narrower aspect to QOF STROKE 1**	QOF STROKE 1 (The practice can produce a register of patients with stroke or TIA) **Broader aspect to QOF STROKE 5, 6, 7, 8, 12, 13, CV03, CV05.**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
QOF STROKE 7 (The percentage of patients with TIA or stroke who have a record of total cholesterol in the last 15 months) **Narrower aspect to QOF STROKE 1**			CV11 (Number of higher risk TIA cases who are scanned and treated within 24 hours)	CV37 (Participation Rates in the Heart Failure Audit)
QOF STROKE 10 (The percentage of patients with TIA or stroke who have had influenza immunisation in the preceding 1 September to 31 March) **Narrower aspect to QOF STROKE 1**			QOF COPD 10 (The percentage of patients with COPD with a record of FeV1 in the previous 15 months) **Narrower aspect to QOF COPD 1. Related to QOF COPD 8, 13, and 11 (same level)**	CV38 (Participation rates in the Cardiac Rehabilitation Audit)
QOF OB 1 (The practice can produce a register of patients aged 16 and over with a Body Mass Index (BMI) greater than or equal to 30 in the previous 15 months)			QOF DM 2 (The percentage of patients with diabetes whose notes record BMI in the previous 15 months) **Related to QOF DM 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 22, 23, 24, 25**	CV16 (Development of continuing education programmes on stroke units)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for the care of clinical conditions
QOF SMOKING 3 (The percentage of patients with any (or any combination of) the following conditions: coronary heart disease, stroke or TIA, hypertension, diabetes, COPD, CKD, asthma, schizophrenia, bipolar affective disorder or other psychoses, whose notes record smoking status in the previous 15 months) **Broader aspect to QOF SMOKING 4**			QOF DM 5 (The percentage of patients with diabetes who have a record of HbA1c or equivalent in the previous 15 months) **Related to QOF DM 2, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25 (same level)**	CV09 (Proportion of sites with a community stroke team for longer term management attached to the stroke multidisciplinary team)
				CV21 (Proportion of sites with formal links to patient/carer groups)
				VSA11b (Cancer 31-Day Subsequent Treatments Target (Drug Treatments)) **Related to VSA 11a**
				LT14a (Percentage of prevalent haemodialysis (HD) patients with haemoglobin between 10.5 - 12.5 g/dl) **Related to LT14b & LT15 & LT17 & LT18 & LT20a & LT20b & LT21 & LT22 (same level)**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				LT14b (Percentage of prevalent peritoneal dialysis (PD) patients with haemoglobin between 10.5 - 12.5 g/dl) **Related to LT14a & LT15 & LT17 & LT18 & LT20a & LT20b & LT21 & LT22 (same level)**
				LT15 (Percentage of prevalent haemodialysis (HD) patients with URR >65%) **Related to LT14a & LT14b & LT17 & LT18 & LT20a & LT20b & LT21 & LT22 (level)**
				LT17 (Percentage of prevalent haemodialysis patients with phosphate between 1.1 - 1.8 mmol/L) **Related to LT14a & LT14b & LT15 & LT18 & LT20a & LT20b & LT21 & LT22 (same level)**
				LT18 (Percentage of prevalent peritoneal dialysis patients with phosphate between 1.1 - 1.8 mmol/L) **Related to LT14a & LT14b & LT15 & LT17 & LT20a & LT20b & LT21 & LT22 (same level)**
				LT20a (Percentage of peritoneal dialysis patients with blood pressure of less than 130/80 mmHg) **Related to LT14a & LT14b & LT15 & LT17 & LT18 & LT21 & LT22**
				LT20b (Percentage of patients with BP <130/80 mmHg: Tx) **Related to LT14a & LT14b & LT15 & LT17 & LT18 & LT20a & LT21 & LT22 (same level)**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				LT21 (Percentage of prevalent haemodialysis patients with bicarbonate between 20 - 26 mmol/L) **Related to LT14a & LT14b & LT15 & LT17 & LT18 & LT20a & LT20b & LT22 (same level)**
				LT22 (Percentage of prevalent peritoneal dialysis patients with bicarbonate between 22 – 30 mmol/L) **Related to LT14a & LT14b & LT15 & LT17 & LT18 & LT20a & LT20b & LT21 (same level)**
				VSB11 (Prevalence of Breastfeeding at 6-8 weeks)
				QOF DEM 2 (The percentage of patients diagnosed with dementia whose care has been reviewed in the previous 15 months) **Narrower aspect to QOF DEM 1**
				QOF DEM 1 (The practice can produce a register of patients diagnosed with dementia) **Broader aspect to QOF DEM 2**
				QOF MH 9 (The percentage of patients with schizophrenia, bipolar affective disorder and other psychoses with a review recorded in the preceding 15 months.) **Narrower aspect to QOF MH 8.**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF MH 6 (The percentage of [mental health] patients on the register who have a comprehensive care plan documented in the records agreed between individuals, their family and/or carers as appropriate)
				QOF MH 7 (The percentage of patients with schizophrenia, bipolar affective disorder and other psychoses who do not attend the practice for their annual review who are identified and followed up by the practice team within 14 days of non-attendance) **Narrower aspect to QOF MH 8**
				QOF MH 8 (The practice can produce a register of people with schizophrenia, bipolar disorder and other psychoses) **Broader aspect to QOF MH 7 and QOF MH 9.**
				MH12 (The number of people who are moving to recovery as a proportion of those who have completed a course of psychological treatment)
				LT25 (Approach rate - The percentage of potential donors for whom solid organ donation was considered, whose family were approached for consent to donation) **Broader aspect to LT26. Narrower aspect to LT24**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				LT26 (Consent rate - The percentage of potential donors whose families were approached or made the approach for consent to donation who gave consent) **Narrower aspect to LT24 & LT25. Broader aspect to LT27.**
				LT27 (Conversion rate - The percentage of potential donors who became actual donors) **Narrower aspect to LT25 & LT26 & LT24**
				LT24 (Referral rate - The percentage of potential donors referred to a co-ordinator) **Broader aspect to LT25, LT26, & LT27**
				CA51 (Compliance with 3C-100 to 3C-500 measures (chemotherapy services))
				CA45 (Proportion of incident cases reviewed by Multi-Disciplinary Team (MDT) for all cancers)
				CA01 (Percentage compliance with Peer Review by team (breast, lung, colorectal, local and specialist gynaecology, local and specialist urology (including supranetwork testicular and penile, haematology and head & neck)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF CHD 9 (The percentage of patients with coronary heart disease with a record in the previous 15 months that aspirin, an alternative anti-platelet therapy, or an anti-coagulant is being taken (unless a contraindication or side-effects are recorded) **Narrower aspect to QOF CHD 7. Related to QOF CHD 6, 8, 10 and12 (same level)**
				QOF CHD 10 (The percentage of patients with coronary heart disease who are currently treated with a beta blocker (unless a contraindication or side-effects are recorded)) **Related to QOF CHD 6, 8, 9 and 12 (same level) Narrower aspect to QOF CHD 7.**
				QOF CHD 11 (The percentage of patients with a history of myocardial infarction (diagnosed after 1 April 2003) who are currently treated with an ACE inhibitor or Angiotensin II antagonist)
				QOF HF 3 (The percentage of patients with a current diagnosis of heart failure due to LVD who are currently treated with an ACE inhibitor or Angiotensin Receptor Blocker, who can tolerate therapy and for whom there is no contraindication) **Related to QOF HF 2 (same level)**
				CV48 (30 day mortality after first time Coronary Artery Bypass Graft)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				CV49 (30 day mortality after first time aortic valve Replacement)
				CV52 (30 day mortality following congenital heart disease surgery)
				CV29 (Percentage of patients following myocardial infarction discharged on aspirin) **Related to CV 30, 31, 32, 33 (same level) Narrower than QOF HF 2**
				CV30 (Percentage of patients following myocardial infarction discharged on beta-blockers) **Related to CV 29, 31, 32, 33 (same level) Narrower than QOF HF 2**
				CV31 (Percentage of patients following myocardial infarction discharged on statins) **Related to CV 29, 30, 32, 33 (same level) Narrower than QOF HF 2**
				CV32 (Percentage of patients following myocardial infarction discharged on ACE inhibitors) **Related to CV 29, 30, 31, 33 (same level) Narrower than QOF HF 2**
				CV33 (Percentage of patients following myocardial infarction discharged on theinopyridine (clopidogrel)) **Related to CV 29, 30, 31, 32 (same level) Narrower than QOF HF 2**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF PP 2 (The percentage of people with hypertension diagnosed after 1 April 2009 who are given lifestyle advice in the last 15 months for: increasing physical activity, smoking cessation, safe alcohol consumption and healthy diet) **Related to QOF PP1 and QOF BP5 (same level). Narrower than QOF BP 4.**
				QOF HF 4 (The percentage of patients with a current diagnosis of heart failure due to LVD who are currently treated with an ACE inhibitor or Angiotensin Receptor Blocker, who are additionally treated with a beta-blocker licensed for heart failure, or recorded as intolerant to or having a contraindication to beta-blockers. (9 points; thresholds 40 – 60%))
				QOF COPD 1 (The practice can produce a register of patients with COPD) **Broader than QOF COPD 1, 8,13, and 11**
				QOF COPD 13 (The percentage of patients with COPD who have had a review, undertaken by a healthcare professional, including an assessment of breathlessness using the MRC dyspnoea score in the preceding 15 months) **Narrower than QOF COPD 1. Related to 8,10, and 11 (same level)**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF DM 15 (The percentage of patients with diabetes with a diagnosis of proteinuria or micro-albuminuria who are treated with ACE inhibitors (or A2 antagonists)) **Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 16, 17, 18, 19, 21, 22, 23, 24, 25 (same level? Expertise Issue)**
				QOF DM 23 (The percentage of patients with diabetes in whom the last HbA1c is 7 or less (or equivalent test/reference range depending on local laboratory) in the previous 15 months) **Middle Aspect of QOF DM 24, 25, & 7 Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22, 24, 25 (same level – Expertise Issue))**
				QOF DM 24 (The percentage of patients with diabetes in whom the last HbA1c is 8 or less (or equivalent test/reference range depending on local laboratory) in the previous 15 months) **Middle Aspect of QOF DM 23, 25, & 7 Related to QOF DM 2, 5, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22, 23, 25 (Same level)**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF DM 25 (The percentage of patients with diabetes in whom the last HbA1c is 9 or less (or equivalent test/reference range depending on local laboratory) in the previous 15 months) **Broadest Aspect of QOF DM 23, 24, & 7 Related to QOF DM 2, 5, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 22. (same level)**
				QOF DM 7 (patients with diabetes in whom the last HbA1c is 10 or less (or equivalent test/reference range depending on local laboratory) in the previous 15 months) **Narrower than QOF DM 25. Broader than QOF DM 23, 24. Related to QOF DM 2, 5, 9, 10, 11, 12, 13, 15, 16, 17, 19, 18, 21, 22.**
				QOF ASTHMA 3 (The percentage of patients with asthma between the ages of 14 and 19 in whom there is a record of smoking status in the previous 15 months) **Related to QOF ASTHMA 6, 8, 1 (same level)**
				QOF ASTHMA 6 (The percentage of patients with asthma who have had an asthma review in the previous 15 months) **Related to QOF ASTHMA 1, 3, 8** (same level)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF ASTHMA 1 (The practice can produce a register of patients with asthma, excluding patients with asthma who have been prescribed no asthma-related drugs in the previous twelve months) **Related to QOF ASTHMA 6, 3, 8 (same level)**
				QOF EPILEPSY 6 (The percentage of patients age 18 and over on drug treatment for epilepsy who have a record of seizure frequency in the previous 15 months) **Narrower aspect of QOF EPILEPSY 5**
				QOF EPILEPSY 5 (The practice can produce a register of patients aged 18 and over receiving drug treatment for epilepsy) **Broader aspect of QOF EPILEPSY 6, 7 & 8**
				QOF EPILEPSY 7 (The percentage of patients aged 18 and over on drug treatment for epilepsy who have a record of medication review involving the patient and/or carer in the previous 15 months) **Narrower aspect of QOF EPILEPSY 5**
				QOF EPILEPSY 8 (The percentage of patients aged 18 and over on drug treatment for epilepsy who have been seizure free for the last 12 months recorded in the previous 15 months) **Narrower aspect of QOF EPILEPSY 5**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF THYROID 1 (The practice can produce a register of patients with hypothyroidism) **Broader aspect of QOF THYROID 2**
				MR30 (Mortality following a knee replacement)
				MR31 (Mortality following a hip replacement)
				TC03 (Diagnostics waiting times: percentage of patients waiting under 6 weeks)
				QOF SH 1 (The practice can produce a register of women who have been prescribed any method of contraception at least once in the last year, or other appropriate interval e.g. 5 years for an IUS) **Broader aspect of QOF SH 2 and 3**
				QOF SH 2 (The percentage of women prescribed an oral or patch contraceptive method who have also received information from the practice about long acting reversible methods of contraception in the previous 15 months) **Narrower aspect of QOF SH 1. Related to SH 3 (same level)**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF SH 3 (The percentage of women prescribed emergency hormonal contraception at least once in the year by the practice who have received information from the practice about long acting reversible methods of contraception at the time of, or within one month of, the prescription) **Narrower aspect to QOF SH 1. Related to SH2 (same level).**
				HES 1 (Pressure ulcer incidence per 10,000 patients)
				HC22 (Surgical site infections - Knee prosthesis) **Related to HC 23 and 25 (same level) Narrower than HC21**
				HC23 (Surgical site infections - Hip prosthesis) **Related to HC22 and 25 (same level). Narrower than HC21**
				HC25 (Surgical site infections - Hip hemiarthroplasty) **Related to HC22 and 23 (same level) Narrower than HC21**
				QOF STROKE 8 (The percentage of patients with TIA or stroke whose last measured total cholesterol (measured in the previous 15 months) is 5mmol/l or less) **Related to QOF STROKE 5 and 6 (same level) Narrower aspect to QOF STROKE 1**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF STROKE 6 (The percentage of patients with a history of TIA or stroke in whom the last blood pressure reading (measured in the previous 15 months) is 150/90 or less) **Related to QOF STROKE 5 and 8 (same level) Narrower aspect to QOF STROKE 1**
				QOF STROKE 12 (The percentage of patients with a stroke shown to be non-haemorrhagic, or a history of TIA, who have a record that an anti-platelet agent (aspirin, clopidogrel, dipyridamole or a combination), or an anti-coagulant is being taken (unless a contraindication or side effects are recorded)) **Narrower aspect to QOF STROKE 1**
				CV08 (Proportion of sites with early supported discharge team attached to the stroke multidisciplinary team)
				CV19 (Average waiting time for neurovascular clinics)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				QOF SMOKING 4 (The percentage of patients with any (or any combination of) the following conditions: coronary heart disease, stroke or TIA, hypertension, diabetes, COPD, CKD, asthma, schizophrenia, bipolar affective disorder or other psychoses, who smoke and whose notes contain a record that smoking cessation advice or referral to a specialist service, where available, has been offered within the previous 15 months) **Narrower aspect to QOF SMOKING 3**.
				VSC11 (People who in last 6 months, have had enough support from local services or organisations to help manage long-term health condition(s)) **Related to PEXIS 1,2 3, 4, PE15 (same level).**
				ERIC1 (Total Backlog Cost per Occupied Floor Area)
				PE49 (Score for patients who reported that the hospital room or ward was very or fairly clean) **Related to PE 50, 53, 54 (same level)**
				PE50 (Score for patients who reported that the toilets and bathrooms in hospital were very or fairly clean) **Related to PE 49, 53, 54**
				PE53 (Score for patients who reported that doctors always or sometimes washed or cleaned their hands between touching patients**) Related to PE 49, 50, 54 (same level)**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PE54 (Score for patients who reported that nurses always or sometimes washed or cleaned their hands between touching patients) **Related to PE 49, 50, 53 (same level)**
				PE41 (Score for patients who reported that they always or sometimes had confidence and trust in the doctors treating them)
				PE42 (Score for patients who reported that when they had important questions to ask a nurse, they always or sometimes got answers they could understand) **Related to PE43, PE18 and PE19 (same level)**
				PE43 (Score for patients who reported that they always or sometimes had confidence and trust in the nurses treating them) **Related to PE42 (same level)**
				PE36 (Score for patients who said they were given enough privacy when being examined or treated) **Narrower than PE37. Broader than PE35**
				PE37 (Score for patients who overall felt they were treated with respect and dignity whilst in hospital) **Broader aspect to PE 33, 34, 36, 38, 39. Probably Redundant to PEXIS 8 and PEAT 3.**
				PE38 (Score for patients who reported that the doctors did not talk in front of them as if they were not there) **Narrower aspect to PE 37**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PE39 (Score for patients who reported that the nurses did not talk in front of them as if they were not there) **Narrower aspect to PE 37**
				PE56 (Score for whether given enough privacy when being examined or treated in the Emergency Department) **Narrower aspect to PE37**
				PE48 (Score for patients who reported that they were not bothered by noise at night from hospital staff) **Narrower aspect to PE37**
				PE51 (Score for patients who reported that the hospital food was very good or good) **Related to PE52 (same level) Narrower than PEAT 2**
				PE52 (Score for patients who reported that they were offered a choice of food) **Related to PE 51 (same level) Narrower than PEAT 2**
				PEAT 1 (A yearly assessment of the Patient Environment for all sites with 10 or more in patient beds) Eg, Points for infection control and cleanliness. **Related to PE49, 50 (same level)**
				PEAT 2 (A yearly assessment of the Food and Food Service for all sites with 10 or more in patient beds) **Broader than PE 51, 52, PE 06**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PEAT 3 (A yearly assessment of Privacy & Dignity for all sites with 10 or more in patient beds) **Related to PE 33, 34, 36, 37, 38, 39 (same level) Broader than PE 36, 38, 39, 56. Probably Redundant to PE 37 and PEXIS 8**
				PEXIS 1 (Patient Experience Headline score for Access & Waiting) **Broader than PE 04, 05, 11**
				PEXIS 2 (Patient Experience Headline score for safe high quality coordinated care) **Narrower than PE23**
				PEXIS 3 (Patient Experience Headline score for Better Information, more choice) **Broader than PE15**
				PEXIS 4 (Patient Experience Headline score for Building Closer Relationships)
				PEXIS 5 (Patient Experience Headline score for Clean, comfortable, friendly place to be) **Related to PE 48, 49, 50, 53, 54, PEAT 1**
				PEXIS 6 (Patient Experience Headline score for Focus on the person) **Vague**
				PEXIS 7 (Patient Experience Headline score for organisation that learns from experience) **Vague**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PEXIS 8 (Patient Experience Headline score for Focus on Dignity and Respect) **Related to PE 36,37,38,39. Broader than PE 33, 34, 36, 38, 39, 56. Probably Redundant to PE 37 and PEAT 3**
				PE 58 (Score for staffing effectiveness - patient reported nursestaffing adequacy)
				CA25 (Quality of Patient Experience: percentage compliance with patient experience measures)
				PE07 (Score for patients who reported that their family or someone close had the opportunity to talk to a doctor if they wanted to) **Broader than PE24.**
				PE08 (Score for patients who said that they found a member of hospital staff to talk to about their worries and fears)
				PE15 (Score for patients who reported that the 'right amount' of information was given about conditions/treatments by healthcare professionals) **Narrower than PEXIS 3**
				PE16 (Score for patients who reported that they were involved as much as they wanted to be in decisions about their care and treatment
				PE18 (Score for patients who reported that when leaving hospital they were given written or printed information about what they should or should not do) **Narrower than PE15**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PE19 (Score for patients who reported that staff explained the purpose of the medicines they were to take at home in a way they could understand) **Related to PE 42, 21, 22 (same level)**
				PE21 (Score for patients who reported that staff told them how to take their medication in a way they could understand) **Related to PE42, 19, 22 (same level). Broader than PE 20.**
				PE22 (Score for patients who reported they were given clear written or printed information about their medicines) **Related to PE42, 19, 21. Broader than PE20.**
				PE26 (Score for patients who reported that they received copies of letters sent between hospital doctors and their GP)
				PE29 (Score for patients who reported that whilst in hospital they saw posters or leaflets explaining how to complain about the care or treatment they received) **Narrower than PE16 and PEXIS 4**
				PE33 (Score for patient who reported that after moving wards they did not share a sleeping area with a member of the opposite sex) **Narrower than PEAT 3 and PEXIS 8**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PE34 (Score for patients who reported that they did not have to use the same bathroom or shower area as patients of the opposite sex) **Narrower than PEAT 3, PE37 and PEXIS 8**
				PE35 (Score for patients who said they were given enough privacy when discussing their condition or treatment) **Narrower than PEAT 3, PE37 and PEXIS 8. Narrower than PE36 (discussion vs examination).**
				PEAT 2 (Score for patients who reported that they always or sometimes got enough help from staff to eat their meals) **Narrower than PE 02**
				PE 94 (Score for patients who reported that their admission date was not changed by the hospital) **Narrower than PEXIS 1**
				PE 05 (Score for patients who reported that on arrival at the hospital they did not have to wait a long time to get a bed on a ward) **Narrower than PEXIS 1**
				PE17 (Score for patients who reported that they were involved in decisions about their discharge from hospital)
				PE09 (Score for patients who thought that the hospital staff did everything they could to help control their pain)

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				PE 28 (Score of [sic] for patients who reported that during their hospital stay they were asked to give their views on the quality of care)
				PE 27 (Percentage of staff who reported that in the last month they had seen any errors, near misses or incidents that could have hurt patients/service) users
				PE 20 (Score for patients who reported that staff told them about medication side effects to watch out for when they went home) **Narrower than PE 21, 23**
				PE23 (Score for patients who reported that staff told them about any danger signals to watch out for after they went home) **Broader than PE 20**
				PE24 (Score for patients who reported that the doctors or nurses gave their family or someone close to them all the information they needed to help care for them) **Narrower than PE07**
				PE25 (Score for patients who reported they were told who to contact if they were worried about their condition or treatment after they left hospital)
				PE11 (Percentage of patients very or fairly satisfied with the time they had to wait from being referred by their GP to when they saw the hospital specialist) **Narrower than PEXIS 1**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				CV43 (Median waiting times (weeks) for echocardiogram)
				CA35a (Percentage of Bowel Cancer patients seeing a relevant specialist nurse)
				CA35b (Percentage of Lung Cancer patients seeing a relevant specialist nurse)
				PS39 (Incidence of MRSA bacteraemia)
				VS03 (Incidence of clostridium difficile)
				HC21 (Surgical site infections – orthopaedic) **Broader than HC 22, 23, 24, 25**
				NRLS1 (Consistent reporting of patient safety events reported to the Reporting and Learning System (RLS)) **Related to NRLS 2 (same level) Narrower than NRLS 3.**
				PS24 (Availability of hand washing facilities)
				PS37 (Sickness Absence Rate)
				NRLS 2 (Timely reporting of patient safety events reported to the Reporting and Learning System (RLS)) **Related NRLS1 (same level) Narrower than NRLS 3.**
				NRLS 3 (Rate of patient safety events occurring in trusts that were submitted to the Reporting and Learning System (RLS**)) Broader than NRLS 1, 2**

Screening and Prevention	Diagnosis and prediagnosis management of patients	Indications for use of surgical procedures	Appropriate use of specific technologies and tests as part of clinical care	Indicators for care of clinical conditions
				MH06 (The proportion of those patients on Care programme approach (CPA) discharged from inpatient care who are followed up within 7 days) **Related to MH 16, 17 (same level)**
				MH16 (NI 149: Adults receiving secondary mental health services on Care Programme Approach (CPA) in settled accommodation) **Related to MH 06, 17 (same level)**
				MH17 (NI150: Adults receiving secondary mental health services on Care Programme Approach (CPA) in employment) **Related to MH 06, 16 (same level)**
				QOF CKD 1 (The practice can produce a register of patients aged 18 years and over with CKD (US National Kidney Foundation: Stage 3 to 5 CKD)) **Broader aspect to QOF CKD 2, 3, 5**
				PE04 (Score for patients who reported that their admission date was not changed by the hospital) **Narrower than PEXIS1.**
				PE06 (Score for patients who reported that they always or sometimes got enough help from staff to eat their meals) **Narrower than PEAT2**.
				VSA03 (Incidence of clostridium difficile)

Appendix 5: Layers of Inclusion/Exclusion Criteria

This appendix lists layers of inclusion and exclusion criteria. Inclusion criteria are taken from the indicator Statement. Exclusion criteria are taken from any NHS HSCIC metadata field that mentions "excludes" or a similar word or phrase.

Indicator	Layers of Inclusion Criteria	Layers of Exclusion Criteria
CV35	1) ST-elevation myocardial infarction (STEMI) patients 2) who received primary angioplasty 3) within 120 minutes of call (call to balloon time)	
CV36	1) ST-elevation myocardial infarction (STEMI) patients 2) who received thrombolytic treatment 3) within 60 minutes of call (call to needle time) 4) who [also] received primary angioplasty 5) within 120 minutes of call (call to balloon time)	
CV34	1) ST-elevation myocardial infarction (STEMI) patients 2) who received thrombolytic treatment 3) within 60 minutes of call (call to needle time)	
RA18	1) fractured proximal femur 2) Emergency readmissions to hospital 3) within 28 days of discharge	1) Day cases OR Spells with a discharge code of death (Denominator)
RA17	1) hip replacement surgery 2) Emergency readmissions to hospital 3) within 28 days of discharge	1) CIP spells with a discharge code of death (Denominator)
RA20	1) stroke 2) Emergency readmissions to hospital 3) within 28 days of discharge	
RA24	1) hysterectomy 2) Emergency readmissions to hospital 3) within 28 days of discharge	1) spells with a discharge coded as death [Denominator]
RA25	1) gallbladder surgery 2) Emergency readmissions to hospital	
RA26	1) abdominal aortic aneurysm surgery 2) Elective Readmissions	
CV02	1) stroke patients 2) given a brain scan 3) within 24 hours of stroke	1) Cases with subarachnoid haemorrhage, subdural and extradural haematoma
CV06	1) stroke patients 2) given a swallow screening 3) within 24 hours of admission	
CV13	1) Acute [stroke] units with 5/6 key characteristics 2) continuous physiological monitoring 3) access to scanning a) within 3 hours of admission 4) 24 hour brain imaging	

	5) policy for direct admission from A&E 6) specialist ward round a) at least 5 times a week	
CV14	1) Acute [stroke] units 2) access to scanning a) within 3 hours of admission	1) Rehabilitation sites
CV01	1) stroke patients 2) given Aspirin or alternative e.g. clopidogrel 3) within 48 hours of stroke	1) patient is receiving palliative care OR patient died OR patient has an intra-cerebral haemorrhage
CV10	1) stroke unit patients 2) spending at least 90% of their time on a stroke unit	
CV20	1) Sites offering thrombolysis 2) to stroke patients	1) Excludes rehabilitation only sites
RA01	1) 16+ years old only 2) Emergency readmissions to hospital 3) within 28 days of discharge	
HC24	1) long bone fracture 2) Open reduction	
WCC 2.09	1) children, 2 years and under 2) who complete MMR immunization	
WCC 2.10	1) children, 5 years and under 2) who complete MMR immunisation (1st and 2nd dose)	
WCC 2.11	1) children, 5 years and under 2) who complete DTP immunisation	
CF01	1) patients aged under 16 (on admission) 2) under the care of a psychiatric specialist 3) occupied bed days on adult psychiatric wards	
CF02	1) patients aged 16 or 17, on admission 2) under the care of a psychiatric specialist 3) occupied bed days on adult psychiatric wards	
QOF PC 2	1) multidisciplinary case review meetings 2) where all patients on the palliative care register are discussed 3) at least 3X monthly	
QOF PC 3	1) Register of all patients in need of palliative care/support	
WCC 3.24	1) all deaths 2) that occur at home	
QOF LD 1	1) register of patients with learning disabilities	
QOF AF 4	1) patients with atrial fibrillation 2) with ECG or specialist confirmed diagnosis 3) after 1 April 2009	
QOFAF 1	1) register of patients with atrial fibrillation	
QOF AF 3	1) patients with atrial fibrillation 2) currently treated with anti-coagulation drug therapy or an anti-platelet therapy	

Indicator	Layers of Inclusion Criteria	Layers of Exclusion Criteria
QOF CANCER 3	1) patients with cancer 2) diagnosed within the last 18 months 3) patient review recorded 4) review recorded as occurring within 6 months of the practice receiving confirmation of the diagnosis	
CWT 1	1) Patients urgently referred with suspected cancer 2) first seen by a specialist within two weeks of referral	
QOF CANCER 1	1) register of patients with a diagnosis of cancer	1) non-melanotic skin cancers from 1 April 2003
VSA09	1) women 2) aged 53-70 3) NHS Breast Screening Programme	
VSA10	1) men and women 2) aged up to 75 3) NHS Bowel Cancer Screening Programme	
VSA15	1) women 2) receive results of cervical screening tests 3) within 2 weeks	
WCC 2.23	1) women 2) aged 25-49 and 50-64 3) screened for cervical cancer	
VSA08	1) Breast Symptom 2) 2 week wait	1) urgent referrals for suspected breast cancer
VSA11a	1) Cancer 2) Surgery Treatments 3) 31-Day Subsequent Treatments	
VSA12	1) Cancer 2) Radiotherapy 3) 31-Day Subsequent Treatments	
VSA13	1) Cancer 2) Extended 62-Day Treatment	
WCC 2.25	1) Cancer Patients 2) waiting no more than 31 days for cancer treatment	
QOF CHD 1	1) register of patients with coronary heart disease	
QOF CHD 2	1) newly diagnosed angina (diagnosed after 1 April 2003) 2) referred for exercise testing and/or specialist assessment	

Indicator	Layers of Inclusion Criteria	Layers of Exclusion Criteria
QOF CHD 5	1) patients with coronary heart disease 2) whose notes have a record of blood pressure 3) in the previous 15 months	
QOF CKD 2	1) patients on the CKD register 2) whose notes have a record of blood pressure 3) in the previous 15 months	
QOF CKD 1	1) register of patients with CKD (US National Kidney Foundation: Stage 3 to 5 CKD) 2) who are aged 18 years and over	
QOF CKD 3	1) patients on the CKD register 2) whom the last blood pressure reading, measured in the previous 15 months 3) is 140/85 or less	
QOF CKD 5	1) patients on the CKD register 2) with hypertension and proteinuria 3) who are treated with an angiotensin converting enzyme inhibitor (ACE-I) or angiotensin receptor blocker (ARB)	1) (unless a contraindication or side effects are recorded)
QOF HF 1	1) register of patients with heart failure	
QOF BP 1	1) register of patients with established hypertension	
QOF STROKE 1	1) register of patients with stroke or TIA	
CV47	1) acute coronary syndrome patients 2) who are seen by a cardiologist 3) during admission	
CV37	1) Heart Failure Audit participants	
CV38	1) Cardiac Rehabilitation Audit	1) Submission of less than 20 cases per month OR less than 70% case ascertainment
CV16	1) continuing education programmes for Stroke Unit staff	
CV09	1) sites with a stroke multidisciplinary team 2) with a community stroke team for longer term management	
CV21	1) sites with formal links to patient/carer groups	
CA36	1) bowel cancer cases	
CA40	1) surgical specimen 2) Median number of lymph nodes examined	
CA41	1) Histological Confirmation Rate	
VSA11b	1) Cancer Drug Treatments 2) 31-Day Subsequent Treatments Target	

Indicator	Layers of Inclusion Criteria	Layers of Exclusion Criteria
LT13	1) patients presenting to a nephrologist 2) RRT initiation 3) less than 90 days before RRT initiation	1) centres in the years where 10% or more of the patients were reported to have started RRT on the same date as the first presentation
LT14a	1) prevalent haemodialysis (HD) patients 2) with haemoglobin between 10.5 - 12.5 g/dl	1) Less than 20 patients with a haemoglobin measurement 2) Less than 50% of the relevant patients had an Hb measurement available
LT14b	1) prevalent peritoneal dialysis (PD) patients 2) with haemoglobin between 10.5 - 12.5 g/dl	1) Less than 20 patients with a haemoglobin measurement 2) Less than 50% of the relevant patients had an Hb measurement available
LT15	1) prevalent haemodialysis (HD) patients 2) with URR >65%	1) Less than 20 patients with a URR value 2) Less than 50% of the relevant patients had a URR value available
LT17	1) prevalent haemodialysis patients 2) with phosphate between 1.1 - 1.8 mmol/L	1) Less than 50% of the relevant patients had a URR value available 2) Less than 20 patients with a URR value
LT18	1) prevalent peritoneal dialysis patients 2) with phosphate between 1.1 - 1.8 mmol/L	1) Less than 20 patients with a phosphate value 2) Less than 50% of the relevant patients had a [phosphate] value available

LT20a	1) [peritoneal dialysis] patients 2) with BP <130/80 mmHg:PD	1) Less than 20 patients with a [BP] value 2) Less than 50% of the relevant patients had a [BP] value available
LT20b	1) [peritoneal dialysis] patients 2) with BP <130/80 mmHg:Tx	1) Less than 20 patients with a [BP] value 2) Less than 50% of the relevant patients had a [BP] value available
LT21	1) prevalent haemodialysis patients 2) with bicarbonate between 20 - 26 mmol/L	1) Less than 20 patients with a [bicarbonate] value 2) Less than 50% of the relevant patients had a [bicarbonate] value available
LT22	1) prevalent peritoneal dialysis patients 2) with bicarbonate between 22 – 30 mmol/L	1) Less than 20 patients with a [bicarbonate] value 2) Less than 50% of the relevant patients had a [bicarbonate] value available
VSB06	1) Pregnant women 2) who have seen a midwife or a maternity healthcare professional 3) for health and social care assessment of needs, risks and choices 4) by 12 weeks and 6 days of pregnancy	
VSB11	1) Breastfeeding 2) at 6-8 weeks	
WCC 2.06	1) pregnancy 2) smoking	
QOF DEM 1	1) register of patients diagnosed with dementia	
QOF DEP 2	1) patients with a new diagnosis of depression 2) recorded between the preceding 1 April to 31 March 3) at the outset of treatment 4) patients who have had an assessment of severity	
QOF DEP 1	1) patients on the diabetes register and/or the CHD register 2) for whom case finding for depression has been undertaken 3) using two standard screening questions 4) on one occasion during the previous 15 months	

QOF MH 9	1) patients with schizophrenia, bipolar affective disorder and other psychoses 2) with a review recorded in the preceding 15 months. 3) In the review there should be evidence that the patient has been offered routine health promotion and prevention advice appropriate to their age, gender and health status	
QOF MH 4	1) patients on lithium therapy 2) with a record of serum creatinine and TSH in the preceding 15 months	
QOF MH 6	1) [Mental Health] patients on the register 2) who have a comprehensive care plan documented in the records agreed between individuals, their family and/or carers as appropriate	
QOF MH 7	1) patients with schizophrenia, bipolar affective disorder and other psychoses 2) who do not attend the practice for their annual review who are identified 3) and [are] followed up by the practice team 4) within 14 days of non-attendance	
QOF MH 8	1) register of people with schizophrenia, bipolar disorder and other psychoses	
QOF MH 5	1) patients on lithium therapy 2) with a record of lithium levels in the therapeutic range 3) within the previous 6 months	
[QOF] MH 12	1) [Patients] who have completed a course of psychological treatment 2) who are moving to recovery	
LT25	1) potential donors for whom solid organ donation 2) was considered 3) whose family were approached for consent to donation	1) absolute contraindications
LT26	1) potential donors for whom solid organ donation 2) was considered 3) whose family were approached for consent to donation 4) who gave consent	1) absolute contraindications
LT27	1) potential [organ] donors 2) who became actual donors	1) absolute contraindications
LT24	1) potential [organ] donors 2) referred to a co-ordinator	1) absolute contraindications
CA27	1) Pathology services 2) compliance with 3D measures	
CA28	1) Imaging services 2) compliance with 3B measures	
CA29	1) Radiotherapy 2) compliance with 3E measures	
CA51	1) chemotherapy services 2) Compliance with 3C-100 to 3C-500 measures	
CA45	1) Cancer incident cases 2) reviewed by Multi-Disciplinary Team (MDT)	
CA01	1) [Cancer] 2) compliance with Peer Review by	

	team (breast, lung, colorectal, local and specialist gynaecology, local and specialist urology (including supranetwork testicular and penile, haematology and head & neck	
CA42a	1) [Bowel Cancer] 2) cases staged 3) at presentation	No longer in use.
CA42b	1) [Head & Neck Cancer] 2) cases staged 3) at presentation	
CA42c	1) [Lung Cancer] 2) cases staged 3) at presentation	No longer in use
QOF CHD 6	1) patients with coronary heart disease 2) in whom the last blood pressure reading (measured in the previous 15 months) 3) is 150/90 or less	
QOF CHD 7	1) patients with coronary heart disease 2) whose notes have a record of total cholesterol 3) in the previous 15 months	
QOF CHD 8	1) patients with coronary heart disease 2) whose last measured total cholesterol (measured in the previous 15 months) 3) is 5mmol/l or less	
QOF CHD 9	1) patients with coronary heart disease 2) with a record in the previous 15 months 3) that aspirin, an alternative anti-platelet therapy, or an anti-coagulant is being taken	(unless a contraindication or side-effects are recorded)
QOF CHD 10	1) patients with coronary heart disease 2) who are currently treated with a beta blocker	(unless a contraindication or side-effects are recorded)
QOF CHD 11	1) patients with a history of myocardial infarction 2) (diagnosed after 1 April 2003) 3) who are currently treated with an ACE inhibitor or Angiotensin II antagonist	
QOF CHD 12	1) patients with coronary heart disease 2) who have a record of influenza immunisation 3) in the preceding 1 September to 31 March	
QOF HF 2	1) patients with a diagnosis of heart failure 2) (diagnosed after 1 April 2006) 3) which has been confirmed by an echocardiogram or by specialist assessment	
QOF HF 3	1) patients with a current diagnosis of heart failure 2) due to LVD 3) who are currently treated with an ACE inhibitor or Angiotensin Receptor Blocker, 4) who can tolerate therapy	1) and for whom there is no contraindication
QOF BP 4	1) patients with hypertension 2) in whom there is a record of the blood pressure 3) in the previous 9 months	
QOF BP 5	1) patients with hypertension 2) in whom the last blood pressure (measured in the previous 9 months) 3) is 150/90 or less	
CV48	1) first time CABG 2) 30 day mortality after	

	3) first time Coronary Artery Bypass Graft	
CV49	1) first time aortic valve replacement 2) 30 day mortality after	
CV52	1) congenital heart disease surgery 2) 30 day mortality following	1) patient has not had further procedures (reoperation) 2) within 30 days or 1 year
CV29	1) myocardial infarction patients 2) discharged on aspirin	1) Aspirin contraindicated OR Treatment declined OR transferred to another hospital
CV30	1) myocardial infarction patients 2) discharged on beta-blockers	1) Beta-blockers contraindicated OR Declined treatment OR Transferred to another hospital
CV31	1) myocardial infarction patients 2) discharged on statins	1) Died in hospital OR Transferred elsewhere
CV32	1) myocardial infarction patients following 2) discharged on ACE inhibitors	1) ACE inhibitors contraindicated OR Declined treatment OR Transferred to another hospital
CV33	1) myocardial infarction patients 2) discharged on theinopyridine (clopidogrel)	1) Clopidogrel contraindicated OR Treatment declined OR Transferred to another hospital
QOF PP 1	1) patients with a new diagnosis of hypertension 2) recorded between the preceding 1 April and 31 March 3) who have had a face to face cardiovascular risk assessment at the outset of diagnosis (within three months of the initial diagnosis) 4) using an agreed risk assessment treatment tool	(excluding those with pre-existing CHD, diabetes, stroke and/or TIA)
QOF PP 2	1) people with hypertension 2) diagnosed after 1 April 2009 3) who are given lifestyle advice for: increasing physical activity, smoking cessation, safe alcohol consumption and healthy diet 4) in the last 15 months	
QOF HF 4	1) patients with a current diagnosis of heart failure 2) due to LVD 3) who are currently treated with an ACE inhibitor or Angiotensin Receptor Blocker, 4) who are additionally treated with a beta-blocker licensed for heart failure, or recorded as intolerant to or having a contraindication to beta-blockers. (9 points; thresholds 40 – 60%)	

QOF COPD 12	1) patients with COPD 2) diagnosed after 1st April 2009 3) in whom the diagnosis has been confirmed by post bronchodilator spirometry	
QOF COPD 10	1) patients with COPD 2) with a record of FeV1 3) in the previous 15 months	
QOF COPD 1	1) register of patients with COPD	
QOF COPD 8	1) patients with COPD 2) who have had influenza immunisation 3) in the preceding 1 September to 31 March	
QOF COPD 13	1) patients with COPD 2) who have had a review, undertaken by a healthcare professional 3) including an assessment of breathlessness 4) using the MRC dyspnoea score 5) in the preceding 15 months	
QOF COPD 11	1) patients with COPD 2) receiving inhaled treatment 3) In whom there is a record that inhaler technique has been checked 4) in the previous 15 months	
QOF DM 21	1) patients with diabetes 2) who have a record of retinal screening 3) in the previous 15 months	
QOF DM 9	1) patients with diabetes 2) with a record of the presence or absence of peripheral pulses 3) in the previous 15 months	
QOF DM 10	1) patients with diabetes 2) with a record of neuropathy testing 3) in the previous 15 months	
QOF DM 11	1) patients with diabetes 2) who have a record of the blood pressure 3) in the previous 15 months	
QOF DM 13	1) patients with diabetes 2) who have a record of micro-albuminuria testing 3) in the previous 15 months (exception reporting for patients with proteinuria)	
QOF DM 22	1) patients with diabetes 2) who have a record of estimated glomerular filtration rate (eGFR) or serum creatinine testing 3) in the previous 15 months	
QOF DM 19	1) register of all patients with diabetes mellitus 2) aged 17 years and over, 3) which specifies whether the patient has Type 1 or Type 2 diabetes	
QOF DM 2	1) patients with diabetes 2) whose notes record BMI 3) in the previous 15 months	
QOF DM 5	1) patients with diabetes 2) who have a record of HbA1c or equivalent 3) in the previous 15 months	
QOF DM 12	1) patients with diabetes 2) in whom the last blood pressure reading is 145/85 or less	
QOF DM 15	1) patients with diabetes	

	2) with a diagnosis of proteinuria or micro-albuminuria 3) who are treated with ACE inhibitors (or A2 antagonists)	
QOF DM 16	1) patients with diabetes 2) who have a record of total cholesterol 3) in the previous 15 months	
QOF DM 17	1) patients with diabetes 2) whose last measured total cholesterol is 5mmol/l or less 3) within the previous 15 months	
QOF DM 18	1) patients with diabetes 2) who have had influenza immunisation 3) in the preceding 1 September to 31 March	
QOF DM 23	1) patients with diabetes 2) in whom the last HbA1c is 7 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF DM 24	1) patients with diabetes 2) in whom the last HbA1c is 8 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF DM 25	1) percentage of patients with diabetes 2) in whom the last HbA1c is 9 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF DM 7	1) patients with diabetes 2) in whom the last HbA1c is 10 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF ASTHMA 8	1) patients aged eight and over 2) diagnosed as having asthma 3) with measures of variability or reversibility 4) from 1 April 2006	
QOF ASTHMA 3	1) patients with asthma 2) between the ages of 14 and 19 3) in whom there is a record of smoking status 4) in the previous 15 months	
QOF ASTHMA 6	1) patients with asthma 2) who have had an asthma review 3) in the previous 15 months	
QOF ASTHMA 1	1) register of patients with asthma	1) excluding patients with asthma who have been prescribed no asthma-related drugs 2) in the previous twelve months
QOF EPILEPSY 6	1) [epilepsy] patients 2) age 18 and over 3) on drug treatment for epilepsy 4) who have a record of seizure frequency 5) in the previous 15 months	
QOF EPILEPSY	1) register of [epilepsy] patients 2) aged 18 and over	

5	3) receiving drug treatment for epilepsy	
QOF EPILEPSY 7	1) [epilepsy] patients 2) aged 18 and over 3) on drug treatment for epilepsy 4) who have a record of medication review involving the patient and/or carer 5) in the previous 15 months	
QOF EPILEPSY 8	1) [epilepsy] patients 2) aged 18 and over 3) on drug treatment for epilepsy 4) who have been seizure free for the last 12 months 5) recorded in the previous 15 months	
QOF THYROID 2	1) patients with hypothyroidism 2) with thyroid function tests recorded 3) in the previous 15 months	
QOF THYROID 1	1) register of patients with hypothyroidism	
TC05	1) BADS (British Association of Day Surgery) Directory of Procedures 2) (including electronic assessment) 3) carried out as a day case or within appropriate length of stay	
MR30	1) knee replacement 2) Mortality following	
MR31	1) hip replacement 2) Mortality following	
TC03	1) Diagnostics patients 2) waiting under 6 weeks	
QOF DEP 3	1) patients with a new diagnosis of depression and assessment of severity 2) recorded between the preceding 1 April to 31 March, 3) the percentage of patients who have had a further assessment of severity 4) 5-12 weeks (inclusive) after the initial recording of the assessment of severity. 5) Both assessments should be completed using an assessment tool validated for use in primary care	
QOF CKD 6	1) patients on the CKD register 2) whose notes have a record of an albumin:creatinine ratio (or protein:creatinine ratio) test 3) in the previous 15 months	
QOF SH 1	1) register of women who have been prescribed any method of contraception 2) at least once in the last year, or other appropriate interval e.g. 5 years for an IUS	
QOF SH 2	1) women prescribed an oral or patch contraceptive method 2) who have also received information from the practice about long acting reversible methods of contraception 3) in the previous 15 months	
QOF SH 3	1) women prescribed emergency hormonal contraception 2) at least once in the year by the practice 3) who have received information from the practice about long acting reversible methods of contraception 4) at the time of, or within one month of, the prescription	
HES 1	1) 10,000 patients	

	2) Pressure ulcer incidence per	
HC22	1) Knee prosthesis 2) Surgical site infections	
HC23	1) Hip prosthesis 2) Surgical site infections	
HC25	1) Hip hemiarthroplasty 2) Surgical site infections	
QOF STROKE 13	1) new patients with a stroke or TIA 2) who have been referred for further investigation	
QOF STROKE 5	1) patients with TIA or stroke 2) who have a record of blood pressure in the notes 3) in the preceding 15 months	
QOF STROKE 7	1) patients with TIA or stroke 2) who have a record of total cholesterol 3) in the last 15 months	
QOF STROKE 8	1) patients with TIA or stroke 2) whose last measured total cholesterol) is 5mmol/l or less 3) (measured in the previous 15 months)	
QOF STROKE 6	1) patients with a history of TIA or stroke 2) in whom the last blood pressure reading is 150/90 or less 3) measured in the previous 15 months	
QOF STROKE 12	1) patients with a stroke 2) shown to be non-haemorrhagic, 3) or a history of TIA, 4) who have a record that an anti-platelet agent (aspirin, clopidogrel, dipyridamole or a combination), or an anti-coagulant is being taken	unless a contraindication or side effects are recorded
QOF STROKE 10	1) patients with TIA or stroke 2) who have had influenza immunisation 3) in the preceding 1 September to 31 March	
CV03	1) stroke patients 2) given a mood assessment	1) if patient unconscious throughout or patient died within 7 days
CV08	1) sites with early supported discharge team 2) attached to the stroke multidisciplinary team	
CV05	1) stroke patients 2) who see Physiotherapist 3) within 72 hours of admission	
CV11	1) higher risk TIA cases 2) who are scanned 3) and treated within 24 hours	
CV19	1) neurovascular clinics 2) Average waiting time	1) sites who do not provide any service for TIA (e.g. rehabilitation only sites)
CV04	1) stroke patients 2) who see occupational therapist 3) within 4 working days	

QOF OB 1	1) register of patients aged 16 and over 2) with a Body Mass Index (BMI) greater than or equal to 30 3) in the previous 15 months	
QOF SMOKING 3	1) patients with any (or any combination of) the following conditions: coronary heart disease, stroke or TIA, hypertension, diabetes, COPD, CKD, asthma, schizophrenia, bipolar affective disorder or other psychoses, 2) whose notes record smoking status in the previous 15 months	
QOF SMOKING 4	1) patients with any (or any combination of) the following conditions: coronary heart disease, stroke or TIA, hypertension, diabetes, COPD, CKD, asthma, schizophrenia, bipolar affective disorder or other psychoses, 2) who smoke and 3) whose notes contain a record that smoking cessation advice or referral to a specialist service, where available, has been offered 4) within the previous 15 months	
VSC11	1) People with long-term health condition(s) 2) who have had enough support from local services or organisations to help manage long-term health condition(s) 3) in last 6 months	
ERIC1	1) Occupied Floor Area 2) Total Backlog Cost	1) leased-out and licensed-out areas OR areas which are not required for operational purposes (i.e. non-occupied areas
PE49	1) patients who reported 2) that the hospital room or ward 3) was very or fairly clean	
PE50	1) patients who reported 2) that the toilets and bathrooms in hospital 3) were very or fairly clean	
PE53	1) patients who reported 2) that doctors always or sometimes washed or cleaned their hands between touching patients	
PE54	1) patients who reported 2) that nurses always or sometimes washed or cleaned their hands between touching patients	
PE41	1) patients who reported 2) that they always or sometimes had confidence and trust in the doctors treating them	
PE42	1) patients who reported 2) that when they had important questions to ask a nurse, they always or sometimes got answers they could understand	
PE43	1) patients who reported 2) that they always or sometimes had confidence and trust in the nurses treating them	

PE 36	1) patients who said 2) they were given enough privacy when being examined or treated	
PE37	1) patients who overall 2) felt they were treated with respect and dignity whilst in hospital	
PE38	1) patients who reported 2) that the doctors did not talk in front of them as if they were not there	
PE39	1) patients who reported 2) that the nurses did not talk in front of them as if they were not there	
PE56	1) Score for whether given enough privacy 2) when being examined or treated 3) in the Emergency Department	
PE48	1) patients who reported 2) that they were not bothered by noise at night from hospital staff	
PE51	1) patients who reported 2) that the hospital food was very good or good	
PE52	1) patients who reported 2) that they were offered a choice of food	
PEAT 1	1) Environment	
PEAT 2	1) Food and Food Service	
PEAT 3	1) Privacy and dignity	
PEXIS1	1) Patient Experience Headline score 2) for Access & Waiting	
PEXIS2	1) Patient Experience Headline score 2) for safe high quality coordinated care	
PEXIS3	1) Patient Experience Headline score 2) for Better Information, more choice	
PEXIS4	1) Patient Experience Headline score 2) for Building Closer Relationships	
PEXIS5	1) Patient Experience Headline score 2) for Clean, comfortable, friendly place to be	
PEXIS6	1) Patient Experience Headline score 2) for Focus on the person	
PEXIS7	1) Patient Experience Headline score 2) for organisation that learns from experience	
PEXIS8	1) Patient Experience Headline score for Focus on Dignity and Respect	
PE58	1) patient reported 2) nurse staffing adequacy	
CA25	1) compliance 2) with patient experience measures.	
PE07	1) Score for patients who reported 2) that their family or someone close had the opportunity to talk to a doctor if they wanted to	
PE08	1) Score for patients who said 2) that they found a member of hospital staff to talk to about their worries and fears	
PE15	1) Score for patients who reported 2) that the 'right amount' of information was given about conditions/treatments by healthcare professionals	
PE16	1) Score for patients who reported	

	2) that they were involved as much as they wanted to be in decisions about their care and treatment	
PE18	1) Score for patients who reported 2) that when leaving hospital they were given written or printed information about what they should or should not do	
PE19	1) Score for patients who reported 2) that staff explained the purpose of the medicines they were to take at home in a way they could understand	
PE21	1) Score for patients who reported 2) that staff told them how to take their medication in a way they could understand	
PE22	1) Score for patients who reported 2) they were given clear written or printed information about their medicines	
PE26	1) Score for patients who reported 2) that they received copies of letters sent between hospital doctors and their GP	
PE29	1) Score for patients who reported 2) that whilst in hospital they saw posters or leaflets explaining how to complain about the care or treatment they received	
PE33	1) Score for patients who reported 2) that after moving wards they did not share a sleeping area with a member of the opposite sex	
PE34	1) Score for patients who reported 2) that they did not have to use the same bathroom or shower area as patients of the opposite sex	
PE35	1) Score for patients who said 2) they were given enough privacy when discussing their condition or treatment	
PE06	1) Score for patients who reported 2) that they always or sometimes got enough help from staff to eat their meals	
PE04	1) Score for patients who reported 2) that their admission date was not changed by the hospital	
PE05	1) Score for patients who reported 2) that on arrival at the hospital they did not have to wait a long time to get a bed on a ward	
PE17	1) Score for patients who reported 2) that they were involved in decisions about their discharge from hospital	
PE09	1) Score for patients who thought 2) that the hospital staff did everything they could to help control their pain	
PE28	1) Score of for patients who reported 2) that during their hospital stay they were asked to give their views on the quality of care	
PE27	1) Percentage of staff who reported 2) that in the last month they had seen any errors, near misses or incidents that could have hurt patients/service users	
PE20	1) Score for patients who reported 2) that staff told them about medication side effects to watch out for when they went home	
PE23	1) Score for patients who reported 2) that staff told them about any danger signals to watch	

	out for after they went home	
PE24	1) Score for patients who reported 2) that the doctors or nurses gave their family or someone close to them all the information they needed to help care for them	
PE25	1) Score for patients who reported 2) they were told who to contact if they were worried about their condition or treatment after they left hospital	
PE11	1) Percentage of patients 2) very or fairly satisfied with the time they had to wait from being referred by their GP to when they saw the hospital specialist	
CV43	1) echocardiogram 2) Median waiting times (weeks)	1) Less than 20 waiters
CA35a	1) [Bowel Cancer] patients 2) seeing a relevant specialist nurse	
CA35b	1) [Lung Cancer] patients 2) seeing a relevant specialist nurse	
PS39	1) Incidence of MRSA bacteraemia	
VSA03	1) Incidence of clostridium difficile	
HC21	1) orthopaedic 2) Surgical site infections	
NRLS1	1) Consistent reporting of patient safety events reported to the Reporting and Learning System (RLS)	
PS24	1) Availability of hand washing facilities	
PS37	1) Sickness Absence Rate	
NRLS2	1) Timely reporting of patient safety events reported to the Reporting and Learning System (RLS)	
NRLS3	1) Rate of patient safety events occurring in trusts that were submitted to the Reporting and Learning System (RLS)	
MH06	1) The proportion of those [mental health] patients 2) on Care programme approach (CPA) 3) discharged from inpatient care 4) who are followed up within 7 days	
MH16	1) Adults receiving secondary mental health services 2) on Care Programme Approach (CPA) 3) in settled accommodation	
MH17	1) Adults receiving secondary mental health services 2) on Care Programme Approach (CPA) 3) in employment	1) Those who are detained under the Mental Health Act should be excluded [Definition]
CV35	1) ST-elevation myocardial infarction (STEMI) patients 2) who received primary angioplasty 3) within 120 minutes of call (call to balloon time)	
CV36	1) ST-elevation myocardial infarction (STEMI) patients 2) who received thrombolytic treatment 3) within 60 minutes of call (call to needle time) 4) who [also] received primary angioplasty 5) within 120 minutes of call (call to balloon time)	
CV34	1) ST-elevation myocardial infarction (STEMI) patients 2) who received thrombolytic treatment	

	3) within 60 minutes of call (call to needle time)	
RA18	1) fractured proximal femur 2) Emergency readmissions to hospital 3) within 28 days of discharge	1) Day cases OR Spells with a discharge code of death (Denominator)
RA17	1) hip replacement surgery 2) Emergency readmissions to hospital 3) within 28 days of discharge	1) CIP spells with a discharge code of death (Denominator)
RA20	1) stroke 2) Emergency readmissions to hospital 3) within 28 days of discharge	
RA24	1) hysterectomy 2) Emergency readmissions to hospital 3) within 28 days of discharge	1) spells with a discharge coded as death [Denominator]
RA25	1) gallbladder surgery 2) Emergency readmissions to hospital	
RA26	1) abdominal aortic aneurysm surgery 2) Elective Readmissions	
CV02	1) stroke patients 2) given a brain scan 3) within 24 hours of stroke	1) Cases with subarachnoid haemorrhage, subdural and extradural haematoma
CV06	1) stroke patients 2) given a swallow screening 3) within 24 hours of admission	
CV13	1) Acute [stroke] units with 5/6 key characteristics 2) continuous physiological monitoring 3) access to scanning a) within 3 hours of admission 4) 24 hour brain imaging 5) policy for direct admission from A&E 6) specialist ward round a) at least 5 times a week	
CV14	1) Acute [stroke] units 2) access to scanning a) within 3 hours of admission	1) Rehabilitation sites
CV01	1) stroke patients 2) given Aspirin or alternative e.g. clopidogrel 3) within 48 hours of stroke	1) patient is receiving palliative care OR patient died OR patient has an intra-cerebral haemorrhage
CV10	1) stroke unit patients 2) spending at least 90% of their time on a stroke unit	
CV20	1) Sites offering thrombolysis 2) to stroke patients	1) Excludes rehabilitation only sites
RA01	1) 16+ years old only 2) Emergency readmissions to hospital 3) within 28 days of discharge	

HC24	1) long bone fracture 2) Open reduction	
WCC 2.09	1) children, 2 years and under 2) who complete MMR immunization	
WCC 2.10	1) children, 5 years and under 2) who complete MMR immunisation (1st and 2nd dose)	
WCC 2.11	1) children, 5 years and under 2) who complete DTP immunisation	
CF01	1) patients aged under 16 (on admission) 2) under the care of a psychiatric specialist 3) occupied bed days on adult psychiatric wards	
CF02	1) patients aged 16 or 17, on admission 2) under the care of a psychiatric specialist 3) occupied bed days on adult psychiatric wards	
QOF PC 2	1) multidisciplinary case review meetings 2) where all patients on the palliative care register are discussed 3) at least 3X monthly	
QOF PC 3	1) Register of all patients in need of palliative care/support	
WCC 3.24	1) all deaths 2) that occur at home	
QOF LD 1	1) register of patients with learning disabilities	
QOF AF 4	1) patients with atrial fibrillation 2) with ECG or specialist confirmed diagnosis 3) after 1 April 2009	
QOFAF 1	1) register of patients with atrial fibrillation	
QOF AF 3	1) patients with atrial fibrillation 2) currently treated with anti-coagulation drug therapy or an anti-platelet therapy	
QOF CANCER 3	1) patients with cancer 2) diagnosed within the last 18 months 3) patient review recorded 4) review recorded as occurring within 6 months of the practice receiving confirmation of the diagnosis	
CWT 1	1) Patients urgently referred with suspected cancer 2) first seen by a specialist within two weeks of referral	
QOF CANCER 1	1) register of patients with a diagnosis of cancer	1) non-melanotic skin cancers from 1 April 2003
VSA09	1) women 2) aged 53-70 3) NHS Breast Screening Programme	
VSA10	1) men and women 2) aged up to 75 3) NHS Bowel Cancer Screening Programme	
VSA15	1) women 2) receive results of cervical screening tests	

	3) within 2 weeks	
WCC 2.23	1) women 2) aged 25-49 and 50-64 3) screened for cervical cancer	
VSA08	1) Breast Symptom 2) 2 week wait	1) urgent referrals for suspected breast cancer
VSA11a	1) Cancer 2) Surgery Treatments 3) 31-Day Subsequent Treatments	
VSA12	1) Cancer 2) Radiotherapy 3) 31-Day Subsequent Treatments	
VSA13	1) Cancer 2) Extended 62-Day Treatment	
WCC 2.25	1) Cancer Patients 2) waiting no more than 31 days for cancer treatment	
QOF CHD 1	1) register of patients with coronary heart disease	
QOF CHD 2	1) newly diagnosed angina (diagnosed after 1 April 2003) 2) referred for exercise testing and/or specialist assessment	
QOF CHD 5	1) patients with coronary heart disease 2) whose notes have a record of blood pressure 3) in the previous 15 months	
QOF CKD 2	1) patients on the CKD register 2) whose notes have a record of blood pressure 3) in the previous 15 months	
QOF CKD 1	1) register of patients with CKD (US National Kidney Foundation: Stage 3 to 5 CKD) 2) who are aged 18 years and over	
QOF CKD 3	1) patients on the CKD register 2) whom the last blood pressure reading, measured in the previous 15 months 3) is 140/85 or less	
QOF CKD 5	1) patients on the CKD register 2) with hypertension and proteinuria 3) who are treated with an angiotensin converting enzyme inhibitor (ACE-I) or angiotensin receptor blocker (ARB)	1) (unless a contraindication or side effects are recorded)
QOF HF 1	1) register of patients with heart failure	
QOF BP 1	1) register of patients with established hypertension	
QOF STROKE 1	1) register of patients with stroke or TIA	
CV47	1) acute coronary syndrome patients 2) who are seen by a cardiologist 3) during admission	
CV37	1) Heart Failure Audit participants	
CV38	1) Cardiac Rehabilitation Audit	1) Submission of less than 20 cases per month OR less than

		70% case ascertainment
CV16	1) continuing education programmes for Stroke Unit staff	
CV09	1) sites with a stroke multidisciplinary team 2) with a community stroke team for longer term management	
CV21	1) sites with formal links to patient/carer groups	
CA36	1) bowel cancer cases	
CA40	1) surgical specimen 2) Median number of lymph nodes examined	
CA41	1) Histological Confirmation Rate	
VSA11b	1) Cancer Drug Treatments 2) 31-Day Subsequent Treatments Target	
LT13	1) patients presenting to a nephrologist 2) RRT initiation 3) less than 90 days before RRT initiation	1) centres in the years where 10% or more of the patients were reported to have started RRT on the same date as the first presentation
LT14a	1) prevalent haemodialysis (HD) patients 2) with haemoglobin between 10.5 - 12.5 g/dl	1) Less than 20 patients with a haemoglobin measurement 2) Less than 50% of the relevant patients had an Hb measurement available
LT14b	1) prevalent peritoneal dialysis (PD) patients 2) with haemoglobin between 10.5 - 12.5 g/dl	1) Less than 20 patients with a haemoglobin measurement 2) Less than 50% of the relevant patients had an Hb measurement available
LT15	1) prevalent haemodialysis (HD) patients 2) with URR >65%	1) Less than 20 patients with a URR value 2) Less than 50% of the relevant patients had a URR value available
LT17	1) prevalent haemodialysis patients 2) with phosphate between 1.1 - 1.8 mmol/L	1) Less than 50% of the relevant patients had a URR value available 2) Less than 20

		patients with a URR value
LT18	1) prevalent peritoneal dialysis patients 2) with phosphate between 1.1 - 1.8 mmol/L	1) Less than 20 patients with a phosphate value 2) Less than 50% of the relevant patients had a [phosphate] value available
LT20a	1) [peritoneal dialysis] patients 2) with BP <130/80 mmHg:PD	1) Less than 20 patients with a [BP] value 2) Less than 50% of the relevant patients had a [BP] value available
LT20b	1) [peritoneal dialysis] patients 2) with BP <130/80 mmHg:Tx	1) Less than 20 patients with a [BP] value 2) Less than 50% of the relevant patients had a [BP] value available
LT21	1) prevalent haemodialysis patients 2) with bicarbonate between 20 - 26 mmol/L	1) Less than 20 patients with a [bicarbonate] value 2) Less than 50% of the relevant patients had a [bicarbonate] value available
LT22	1) prevalent peritoneal dialysis patients 2) with bicarbonate between 22 – 30 mmol/L	1) Less than 20 patients with a [bicarbonate] value 2) Less than 50% of the relevant patients had a [bicarbonate] value available
VSB06	1) Pregnant women 2) who have seen a midwife or a maternity healthcare professional 3) for health and social care assessment of needs, risks and choices 4) by 12 weeks and 6 days of pregnancy	
VSB11	1) Breastfeeding 2) at 6-8 weeks	
WCC 2.06	1) pregnancy 2) smoking	
QOF DEM 1	1) register of patients diagnosed with dementia	
QOF DEP 2	1) patients with a new diagnosis of depression	

	2) recorded between the preceding 1 April to 31 March 3) at the outset of treatment 4) patients who have had an assessment of severity	
QOF DEP 1	1) patients on the diabetes register and/or the CHD register 2) for whom case finding for depression has been undertaken 3) using two standard screening questions 4) on one occasion during the previous 15 months	
QOF MH 9	1) patients with schizophrenia, bipolar affective disorder and other psychoses 2) with a review recorded in the preceding 15 months. 3) In the review there should be evidence that the patient has been offered routine health promotion and prevention advice appropriate to their age, gender and health status	
QOF MH 4	1) patients on lithium therapy 2) with a record of serum creatinine and TSH in the preceding 15 months	
QOF MH 6	1) [Mental Health] patients on the register 2) who have a comprehensive care plan documented in the records agreed between individuals, their family and/or carers as appropriate	
QOF MH 7	1) patients with schizophrenia, bipolar affective disorder and other psychoses 2) who do not attend the practice for their annual review who are identified 3) and [are] followed up by the practice team 4) within 14 days of non-attendance	
QOF MH 8	1) register of people with schizophrenia, bipolar disorder and other psychoses	
QOF MH 5	1) patients on lithium therapy 2) with a record of lithium levels in the therapeutic range 3) within the previous 6 months	
[QOF] MH 12	1) [Patients] who have completed a course of psychological treatment 2) who are moving to recovery	
LT25	1) potential donors for whom solid organ donation 2) was considered 3) whose family were approached for consent to donation	1) absolute contraindications
LT26	1) potential donors for whom solid organ donation 2) was considered 3) whose family were approached for consent to donation 4) who gave consent	1) absolute contraindications
LT27	1) potential [organ] donors 2) who became actual donors	1) absolute contraindications
LT24	1) potential [organ] donors 2) referred to a co-ordinator	1) absolute contraindications
CA27	1) Pathology services 2) compliance with 3D measures	
CA28	1) Imaging services 2) compliance with 3B measures	

CA29	1) Radiotherapy 2) compliance with 3E measures	
CA51	1) chemotherapy services 2) Compliance with 3C-100 to 3C-500 measures	
CA45	1) Cancer incident cases 2) reviewed by Multi-Disciplinary Team (MDT)	
CA01	1) [Cancer] 2) compliance with Peer Review by team (breast, lung, colorectal, local and specialist gynaecology, local and specialist urology (including supranetwork testicular and penile, haematology and head & neck	
CA42a	1) [Bowel Cancer] 2) cases staged 3) at presentation	No longer in use.
CA42b	1) [Head & Neck Cancer] 2) cases staged 3) at presentation	
CA42c	1) [Lung Cancer] 2) cases staged 3) at presentation	No longer in use
QOF CHD 6	1) patients with coronary heart disease 2) in whom the last blood pressure reading (measured in the previous 15 months) 3) is 150/90 or less	
QOF CHD 7	1) patients with coronary heart disease 2) whose notes have a record of total cholesterol 3) in the previous 15 months	
QOF CHD 8	1) patients with coronary heart disease 2) whose last measured total cholesterol (measured in the previous 15 months) 3) is 5mmol/l or less	
QOF CHD 9	1) patients with coronary heart disease 2) with a record in the previous 15 months 3) that aspirin, an alternative anti-platelet therapy, or an anti-coagulant is being taken	(unless a contraindication or side-effects are recorded)
QOF CHD 10	1) patients with coronary heart disease 2) who are currently treated with a beta blocker	(unless a contraindication or side-effects are recorded)
QOF CHD 11	1) patients with a history of myocardial infarction 2) (diagnosed after 1 April 2003) 3) who are currently treated with an ACE inhibitor or Angiotensin II antagonist	
QOF CHD 12	1) patients with coronary heart disease 2) who have a record of influenza immunisation 3) in the preceding 1 September to 31 March	
QOF HF 2	1) patients with a diagnosis of heart failure 2) (diagnosed after 1 April 2006) 3) which has been confirmed by an echocardiogram or by specialist assessment	
QOF HF 3	1) patients with a current diagnosis of heart failure 2) due to LVD 3) who are currently treated with an ACE inhibitor or Angiotensin Receptor Blocker, 4) who can tolerate therapy	1) and for whom there is no contraindication

QOF BP 4	1) patients with hypertension 2) in whom there is a record of the blood pressure 3) in the previous 9 months	
QOF BP 5	1) patients with hypertension 2) in whom the last blood pressure (measured in the previous 9 months) 3) is 150/90 or less	
CV48	1) first time CABG 2) 30 day mortality after 3) first time Coronary Artery Bypass Graft	
CV49	1) first time aortic valve replacement 2) 30 day mortality after	
CV52	1) congenital heart disease surgery 2) 30 day mortality following	1) patient has not had further procedures (reoperation) 2) within 30 days or 1 year
CV29	1) myocardial infarction patients 2) discharged on aspirin	1) Aspirin contraindicated OR Treatment declined OR transferred to another hospital
CV30	1) myocardial infarction patients 2) discharged on beta-blockers	1) Beta-blockers contraindicated OR Declined treatment OR Transferred to another hospital
CV31	1) myocardial infarction patients 2) discharged on statins	1) Died in hospital OR Transferred elsewhere
CV32	1) myocardial infarction patients following 2) discharged on ACE inhibitors	1) ACE inhibitors contraindicated OR Declined treatment OR Transferred to another hospital
CV33	1) myocardial infarction patients 2) discharged on theinopyridine (clopidogrel)	1) Clopidogrel contraindicated OR Treatment declined OR Transferred to another hospital
QOF PP 1	1) patients with a new diagnosis of hypertension 2) recorded between the preceding 1 April and 31 March 3) who have had a face to face cardiovascular risk assessment at the outset of diagnosis (within three months of the initial diagnosis) 4) using an agreed risk assessment treatment tool	(excluding those with pre-existing CHD, diabetes, stroke and/or TIA)
QOF PP 2	1) people with hypertension 2) diagnosed after 1 April 2009 3) who are given lifestyle advice for: increasing physical activity, smoking cessation, safe alcohol consumption and healthy diet 4) in the last 15 months	

QOF HF 4	1) patients with a current diagnosis of heart failure 2) due to LVD 3) who are currently treated with an ACE inhibitor or Angiotensin Receptor Blocker, 4) who are additionally treated with a beta-blocker licensed for heart failure, or recorded as intolerant to or having a contraindication to beta-blockers. (9 points; thresholds 40 – 60%)	
QOF COPD 12	1) patients with COPD 2) diagnosed after 1st April 2009 3) in whom the diagnosis has been confirmed by post bronchodilator spirometry	
QOF COPD 10	1) patients with COPD 2) with a record of FeV1 3) in the previous 15 months	
QOF COPD 1	1) register of patients with COPD	
QOF COPD 8	1) patients with COPD 2) who have had influenza immunisation 3) in the preceding 1 September to 31 March	
QOF COPD 13	1) patients with COPD 2) who have had a review, undertaken by a healthcare professional 3) including an assessment of breathlessness 4) using the MRC dyspnoea score 5) in the preceding 15 months	
QOF COPD 11	1) patients with COPD 2) receiving inhaled treatment 3) In whom there is a record that inhaler technique has been checked 4) in the previous 15 months	
QOF DM 21	1) patients with diabetes 2) who have a record of retinal screening 3) in the previous 15 months	
QOF DM 9	1) patients with diabetes 2) with a record of the presence or absence of peripheral pulses 3) in the previous 15 months	
QOF DM 10	1) patients with diabetes 2) with a record of neuropathy testing 3) in the previous 15 months	
QOF DM 11	1) patients with diabetes 2) who have a record of the blood pressure 3) in the previous 15 months	
QOF DM 13	1) patients with diabetes 2) who have a record of micro-albuminuria testing 3) in the previous 15 months (exception reporting for patients with proteinuria)	
QOF DM 22	1) patients with diabetes 2) who have a record of estimated glomerular filtration rate (eGFR) or serum creatinine testing 3) in the previous 15 months	
QOF DM 19	1) register of all patients with diabetes mellitus 2) aged 17 years and over, 3) which specifies whether the patient has Type 1 or Type 2 diabetes	

QOF DM 2	1) patients with diabetes 2) whose notes record BMI 3) in the previous 15 months	
QOF DM 5	1) patients with diabetes 2) who have a record of HbA1c or equivalent 3) in the previous 15 months	
QOF DM 12	1) patients with diabetes 2) in whom the last blood pressure reading is 145/85 or less	
QOF DM 15	1) patients with diabetes 2) with a diagnosis of proteinuria or micro-albuminuria 3) who are treated with ACE inhibitors (or A2 antagonists)	
QOF DM 16	1) patients with diabetes 2) who have a record of total cholesterol 3) in the previous 15 months	
QOF DM 17	1) patients with diabetes 2) whose last measured total cholesterol is 5mmol/l or less 3) within the previous 15 months	
QOF DM 18	1) patients with diabetes 2) who have had influenza immunisation 3) in the preceding 1 September to 31 March	
QOF DM 23	1) patients with diabetes 2) in whom the last HbA1c is 7 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF DM 24	1) patients with diabetes 2) in whom the last HbA1c is 8 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF DM 25	1) percentage of patients with diabetes 2) in whom the last HbA1c is 9 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF DM 7	1) patients with diabetes 2) in whom the last HbA1c is 10 or less (or equivalent test/reference range depending on local laboratory) 3) in the previous 15 months	
QOF ASTHMA 8	1) patients aged eight and over 2) diagnosed as having asthma 3) with measures of variability or reversibility 4) from 1 April 2006	
QOF ASTHMA 3	1) patients with asthma 2) between the ages of 14 and 19 3) in whom there is a record of smoking status 4) in the previous 15 months	
QOF ASTHMA 6	1) patients with asthma 2) who have had an asthma review 3) in the previous 15 months	
QOF ASTHMA 1	1) register of patients with asthma	1) excluding patients with asthma who have been prescribed no asthma-related drugs 2) in the

		previous twelve months
QOF EPILEPSY 6	1) [epilepsy] patients 2) age 18 and over 3) on drug treatment for epilepsy 4) who have a record of seizure frequency 5) in the previous 15 months	
QOF EPILEPSY 5	1) register of [epilepsy] patients 2) aged 18 and over 3) receiving drug treatment for epilepsy	
QOF EPILEPSY 7	1) [epilepsy] patients 2) aged 18 and over 3) on drug treatment for epilepsy 4) who have a record of medication review involving the patient and/or carer 5) in the previous 15 months	
QOF EPILEPSY 8	1) [epilepsy] patients 2) aged 18 and over 3) on drug treatment for epilepsy 4) who have been seizure free for the last 12 months 5) recorded in the previous 15 months	
QOF THYROID 2	1) patients with hypothyroidism 2) with thyroid function tests recorded 3) in the previous 15 months	
QOF THYROID 1	1) register of patients with hypothyroidism	
TC05	1) BADS (British Association of Day Surgery) Directory of Procedures 2) (including electronic assessment) 3) carried out as a day case or within appropriate length of stay	
MR30	1) knee replacement 2) Mortality following	
MR31	1) hip replacement 2) Mortality following	
TC03	1) Diagnostics patients 2) waiting under 6 weeks	
QOF DEP 3	1) patients with a new diagnosis of depression and assessment of severity 2) recorded between the preceding 1 April to 31 March, 3) the percentage of patients who have had a further assessment of severity 4) 5-12 weeks (inclusive) after the initial recording of the assessment of severity. 5) Both assessments should be completed using an assessment tool validated for use in primary care	
QOF CKD 6	1) patients on the CKD register 2) whose notes have a record of an albumin:creatinine ratio (or protein:creatinine ratio) test 3) in the previous 15 months	
QOF SH 1	1) register of women who have been prescribed any method of contraception 2) at least once in the last year, or other appropriate interval e.g. 5 years for an IUS	
QOF SH 2	1) women prescribed an oral or patch contraceptive method 2) who have also received information from the practice	

	about long acting reversible methods of contraception 3) in the previous 15 months	
QOF SH 3	1) women prescribed emergency hormonal contraception 2) at least once in the year by the practice 3) who have received information from the practice about long acting reversible methods of contraception 4) at the time of, or within one month of, the prescription	
HES 1	1) 10,000 patients 2) Pressure ulcer incidence per	
HC22	1) Knee prosthesis 2) Surgical site infections	
HC23	1) Hip prosthesis 2) Surgical site infections	
HC25	1) Hip hemiarthroplasty 2) Surgical site infections	
QOF STROKE 13	1) new patients with a stroke or TIA 2) who have been referred for further investigation	
QOF STROKE 5	1) patients with TIA or stroke 2) who have a record of blood pressure in the notes 3) in the preceding 15 months	
QOF STROKE 7	1) patients with TIA or stroke 2) who have a record of total cholesterol 3) in the last 15 months	
QOF STROKE 8	1) patients with TIA or stroke 2) whose last measured total cholesterol) is 5mmol/l or less 3) (measured in the previous 15 months)	
QOF STROKE 6	1) patients with a history of TIA or stroke 2) in whom the last blood pressure reading is 150/90 or less 3) measured in the previous 15 months	
QOF STROKE 12	1) patients with a stroke 2) shown to be non-haemorrhagic, 3) or a history of TIA, 4) who have a record that an anti-platelet agent (aspirin, clopidogrel, dipyridamole or a combination), or an anti-coagulant is being taken	unless a contraindication or side effects are recorded
QOF STROKE 10	1) patients with TIA or stroke 2) who have had influenza immunisation 3) in the preceding 1 September to 31 March	
CV03	1) stroke patients 2) given a mood assessment	1) if patient unconscious throughout or patient died within 7 days
CV08	1) sites with early supported discharge team 2) attached to the stroke multidisciplinary team	
CV05	1) stroke patients 2) who see Physiotherapist 3) within 72 hours of admission	
CV11	1) higher risk TIA cases 2) who are scanned	

	3) and treated within 24 hours	
CV19	1) neurovascular clinics 2) Average waiting time	1) sites who do not provide any service for TIA (e.g. rehabilitation only sites)
CV04	1) stroke patients 2) who see occupational therapist 3) within 4 working days	
QOF OB 1	1) register of patients aged 16 and over 2) with a Body Mass Index (BMI) greater than or equal to 30 3) in the previous 15 months	
QOF SMOKING 3	1) patients with any (or any combination of) the following conditions: coronary heart disease, stroke or TIA, hypertension, diabetes, COPD, CKD, asthma, schizophrenia, bipolar affective disorder or other psychoses, 2) whose notes record smoking status in the previous 15 months	
QOF SMOKING 4	1) patients with any (or any combination of) the following conditions: coronary heart disease, stroke or TIA, hypertension, diabetes, COPD, CKD, asthma, schizophrenia, bipolar affective disorder or other psychoses, 2) who smoke and 3) whose notes contain a record that smoking cessation advice or referral to a specialist service, where available, has been offered 4) within the previous 15 months	
VSC11	1) People with long-term health condition(s) 2) who have had enough support from local services or organisations to help manage long-term health condition(s) 3) in last 6 months	
ERIC1	1) Occupied Floor Area 2) Total Backlog Cost	1) leased-out and licensed-out areas OR areas which are not required for operational purposes (i.e. non-occupied areas
PE49	1) patients who reported 2) that the hospital room or ward 3) was very or fairly clean	
PE50	1) patients who reported 2) that the toilets and bathrooms in hospital 3) were very or fairly clean	
PE53	1) patients who reported 2) that doctors always or sometimes washed or cleaned their hands between touching patients	
PE54	1) patients who reported 2) that nurses always or sometimes washed or cleaned their hands between touching patients	
PE41	1) patients who reported	

	2) that they always or sometimes had confidence and trust in the doctors treating them	
PE42	1) patients who reported 2) that when they had important questions to ask a nurse, they always or sometimes got answers they could understand	
PE43	1) patients who reported 2) that they always or sometimes had confidence and trust in the nurses treating them	
PE 36	1) patients who said 2) they were given enough privacy when being examined or treated	
PE37	1) patients who overall 2) felt they were treated with respect and dignity whilst in hospital	
PE38	1) patients who reported 2) that the doctors did not talk in front of them as if they were not there	
PE39	1) patients who reported 2) that the nurses did not talk in front of them as if they were not there	
PE56	1) Score for whether given enough privacy 2) when being examined or treated 3) in the Emergency Department	
PE48	1) patients who reported 2) that they were not bothered by noise at night from hospital staff	
PE51	1) patients who reported 2) that the hospital food was very good or good	
PE52	1) patients who reported 2) that they were offered a choice of food	
PEAT 1	1) Environment	
PEAT 2	1) Food and Food Service	
PEAT 3	1) Privacy and dignity	
PEXIS1	1) Patient Experience Headline score 2) for Access & Waiting	
PEXIS2	1) Patient Experience Headline score 2) for safe high quality coordinated care	
PEXIS3	1) Patient Experience Headline score 2) for Better Information, more choice	
PEXIS4	1) Patient Experience Headline score 2) for Building Closer Relationships	
PEXIS5	1) Patient Experience Headline score 2) for Clean, comfortable, friendly place to be	
PEXIS6	1) Patient Experience Headline score 2) for Focus on the person	
PEXIS7	1) Patient Experience Headline score 2) for organisation that learns from experience	
PEXIS8	1) Patient Experience Headline score for Focus on Dignity and Respect	
PE58	1) patient reported 2) nurse staffing adequacy	
CA25	1) compliance 2) with patient experience measures.	

PE07	1) Score for patients who reported 2) that their family or someone close had the opportunity to talk to a doctor if they wanted to	
PE08	1) Score for patients who said 2) that they found a member of hospital staff to talk to about their worries and fears	
PE15	1) Score for patients who reported 2) that the 'right amount' of information was given about conditions/treatments by healthcare professionals	
PE16	1) Score for patients who reported 2) that they were involved as much as they wanted to be in decisions about their care and treatment	
PE18	1) Score for patients who reported 2) that when leaving hospital they were given written or printed information about what they should or should not do	
PE19	1) Score for patients who reported 2) that staff explained the purpose of the medicines they were to take at home in a way they could understand	
PE21	1) Score for patients who reported 2) that staff told them how to take their medication in a way they could understand	
PE22	1) Score for patients who reported 2) they were given clear written or printed information about their medicines	
PE26	1) Score for patients who reported 2) that they received copies of letters sent between hospital doctors and their GP	
PE29	1) Score for patients who reported 2) that whilst in hospital they saw posters or leaflets explaining how to complain about the care or treatment they received	
PE33	1) Score for patients who reported 2) that after moving wards they did not share a sleeping area with a member of the opposite sex	
PE34	1) Score for patients who reported 2) that they did not have to use the same bathroom or shower area as patients of the opposite sex	
PE35	1) Score for patients who said 2) they were given enough privacy when discussing their condition or treatment	
PE06	1) Score for patients who reported 2) that they always or sometimes got enough help from staff to eat their meals	
PE04	1) Score for patients who reported 2) that their admission date was not changed by the hospital	
PE05	1) Score for patients who reported 2) that on arrival at the hospital they did not have to wait a long time to get a bed on a ward	
PE17	1) Score for patients who reported 2) that they were involved in decisions about their discharge from hospital	
PE09	1) Score for patients who thought 2) that the hospital staff did everything they could to help control their pain	

PE28	1) Score of for patients who reported 2) that during their hospital stay they were asked to give their views on the quality of care	
PE27	1) Percentage of staff who reported 2) that in the last month they had seen any errors, near misses or incidents that could have hurt patients/service users	
PE20	1) Score for patients who reported 2) that staff told them about medication side effects to watch out for when they went home	
PE23	1) Score for patients who reported 2) that staff told them about any danger signals to watch out for after they went home	
PE24	1) Score for patients who reported 2) that the doctors or nurses gave their family or someone close to them all the information they needed to help care for them	
PE25	1) Score for patients who reported 2) they were told who to contact if they were worried about their condition or treatment after they left hospital	
PE11	1) Percentage of patients 2) very or fairly satisfied with the time they had to wait from being referred by their GP to when they saw the hospital specialist	
CV43	1) echocardiogram 2) Median waiting times (weeks)	1) Less than 20 waiters
CA35a	1) [Bowel Cancer] patients 2) seeing a relevant specialist nurse	
CA35b	1) [Lung Cancer] patients 2) seeing a relevant specialist nurse	
PS39	1) Incidence of MRSA bacteraemia	
VSA03	1) Incidence of clostridium difficile	
HC21	1) orthopaedic 2) Surgical site infections	
NRLS1	1) Consistent reporting of patient safety events reported to the Reporting and Learning System (RLS)	
PS24	1) Availability of hand washing facilities	
PS37	1) Sickness Absence Rate	
NRLS2	1) Timely reporting of patient safety events reported to the Reporting and Learning System (RLS)	
NRLS3	1) Rate of patient safety events occurring in trusts that were submitted to the Reporting and Learning System (RLS)	
MH06	1) The proportion of those [mental health] patients 2) on Care programme approach (CPA) 3) discharged from inpatient care 4) who are followed up within 7 days	
MH16	1) Adults receiving secondary mental health services 2) on Care Programme Approach (CPA) 3) in settled accommodation	
MH17	1) Adults receiving secondary mental health services 2) on Care Programme Approach (CPA) 3) in employment	1) Those who are detained under the Mental Health Act should be

		excluded [Definition]

Appendix 6: Issues Log

This log was established to track issues encountered during the ontology development process. Resolution is recorded in the 'How' column.

Date	Issue	Date Resolved	How
4/3/13	Need to figure out how to delete Indicators as a subclass of Indicators (shows up in Relations mode)		Can't even find Relations mode now, so may not be a problem.
4/3/13	Need to delete subclasses of Indicators that I have now entered as Slots	5/3/13	Done
5/3/13	Need to change Defaults for Topic slot in Planned Care subclass of NSR to subslots or find alternative solution.	18/3/13	Added has_topic_of as a slot for Indicators and NSR pathway
18/3/13	Determine whether redundant classes and slots for Topic/topic are a problem	22/5/13	Get rid of Topic altogether (They are assigned inconsistently by IC anyway). Done
5/3/13	Consider changing subclasses of Dimension and NSR Pathway to instances or can they also be properties of Indicator?	6/3/13	Added as properties
5/3/13	Need expert to check overall framework.	22/4/13	Professor John Chelsom advised Protégé 3.4.1 was poor choice.
6/3/13	Order of properties need to be organised in logical manner in Forms.	15/3/13	Done
7/3/13	Troubleshoot Purpose slot in a similar manner to Topic. Values may need to be recorded differently.	22/5/13 [decision made]	No action taken as slots can also be classes. Purpose is a major component of this research.

Date	Issue	Date Resolved	How
17/3/13	Inclusion/Exclusion Criteria need to be layered from full to minimum instead of 1st layer, 2nd layer, etc. (because slots and subslots include content of narrower slots)	Done 3/13	Consider additional slot for Number of Inclusion Criteria and Number of Exclusion Criteria to handle queries based on Inclusion/Exclusion criteria. This could compensate for backward nature of layers of criteria and enable queries for related indicators to be structured from common and initial criteria inwards..
18/3/13	Have not created slot for NHS IC –assigned Category or Subject. This is because these terms appear arbitrary. A stable clinical terminology should accomplish the same purpose. May be able to delete Topic/topic redundancies using same analogy.		No action needed
18/3/13	Redundant detail in IC categories means I am not always including exact statements.		No action needed.
19/3/13	Just because Exclusion criteria is not stated does not mean there are no exclusion criteria. Does this matter if the criteria are essentially covered in Inclusion criteria?		No action needed.
19/3/13	Future work should consider authority records for associated creators, publishers, etc.		Include in Discussion

Date	Issue	Date Resolved	How
19/3//13 25/3/13	Doublecheck Statement vs Formula (have been taking Formula from Definition or Detailed Descriptor and Statement from Title) back to RA20 For the purposes of this ontology, the formula is taken from the Definition or Detailed Descriptor section of the NHS IC metadata. The Formula/Calculation methodology appears inconsistent, sometimes with just a referring URL and sometimes with extensive detail. Some of this detail would be better included as a note. For this PhD project, the primary objectives are to attempt to distinguish inclusion and exclusion criteria and to assess types of indicator purpose. Stopped this after VSA08. This NHS IC spreadsheet shows how extensive the number of fields would potentially need to be, along with creating relationships between them, to enter complex formulae: http://www.ic.nhs.uk/CHttpHandler.ashx?id=10397&p=0 This seems beyond the scope of this project.		Include in Discussion

Date	Issue	Date Resolved	How
19/3/13	Detailed Descriptor [sometimes entered as Notes, though this may be unnecessary, due to inclusion of URL for complete methodology] for RA24 is so complex and disorganised that alternative fields may be necessary. Detailed descriptor sometimes includes information for specific years of data-gathering, making it potentially unwieldy. Other times, it is very minimal and mainly a referring URL.		Include in Discussion.
20/3/13	Need to record HC24 as Narrower than HC21 (after entering Instance of HC 21) . Nd. To record QOF STROKE 1 as Broader aspect to QOF STROKE 5, 7, 8, 13, CV03, CV05.	NK	Done
22/3/13	Consider whether to fix inconsistent slot values for Related to vs Broader/Narrower Than.	23/3/13	Slot value for Related changed to Instance.
25/3/13	VSA10 is an example of why I am not being consistent with selection of NHS IC – supplied field for Formula. The Formula/Methodology field includes justification, which is more than just a formula or methodology. WCC 2.23 is an example where the Formula/Methodology field includes only a referring URL.		Include in Discussion

Date	Issue	Date Resolved	How
26/3/13	Inconsistencies in Source information for LT13-22 are an example of why authority records are needed. Sometimes Source is listed as UK Renal Registry. Sometime it is listed as National Renal Dataset.		Include in Discussion
26/3/13	LT13-22 (try LT20a) show more examples of Formula vs Detailed Descriptor issue.		Include in Discussion
2/4/13	Need to enter for [QOF] MH12 - PSA 18 Indicator 5 : Improve Access to Psychological Therapies	13/4/13	Done
2/4/13	Need to enter for LT25 - Broader aspect to LT2.	13/4/13	There is no LT2. Thesis corrected.
3/4/13	QOF DM 7 has been recorded inconsistently. Needs to be added to Indicators by Purpose Table (Screening) and relationships entered in table and ontology.	13/4/13	Done
4/4/13	The Query, Common Criteria for CV35 and CV36 (who received primary angioplasty), may need revising as the word 'also' had to be removed from CV36 in order to make it work. Need to check whether this interferes with logic. Also need to consider whether number of layers is a necessary slot.	4/4/13	Done. Reduced key words to 'received primary angioplasty' and restored [also].
5/4/13	Need to record that CV11 is related to VSA14	12/4/13	Not Done. VSA14 is not part of this set.

Date	Issue	Date Resolved	How
7/4/13	Have not included PE49, PE50, PE53, PE54, PE41, PE42, PE43, PE36, PE37, PE38, PE39, PE56, PE48, PE51, PE52 due to status uncertainty and lack of metadata. CF01, CF02: Nd to decide whether to enter [Not entered] Started entering some of these due to relationships. May go back and delete. Also review RA25.	15/4/13	. Have now deleted those that were dropped, no longer in use, or status unknown at the time of indicator analysis.
7/4/13	Need to enter Related info for Patient Experience indicators	11/4/13	Done
8/4/13	Need to add PE06, PE04 and VSA03 to Indicators by Type table in thesis	13/4/13	Done
8/4/13	Create rule for status issue (eg, Dropped at the time I entered data vs Dropped after I entered data, Replaced by)		Include in Discussion
10/4/13	Does the order in which the full inclusion criteria appear matter? (Different issue - Order for some levels of criteria sometimes matter more than others.)		Include in Discussion

Date	Issue	Date Resolved	How
10/4/13	Boolean logic may be an issue for inclusion/exclusion criteria. Eg, OR = same level, but should it be a single statement or 2 entries? Also, dependencies are recorded at same level (eg, access to scanning within 3 hours of admission: 2 concepts, but recorded at same level because within 3 hours of admission must apply to scanning). Temporal issues are recorded inconsistently in this pilot, due to semantics (eg, 1) patients with coronary heart disease 2) with a record in the previous 15 months. Compare the semantics of the next 2 rows:		Include in Discussion
QOF BP 4	1) patients with hypertension 2) in whom there is a record of the blood pressure 3) in the previous 9 months		Include in Discussion
QOF BP 5	1) patients with hypertension 2) in whom the last blood pressure (measured in the previous 9 months) 3) is 150/90 or less		
11/4/13	PS37, MH06, MH16 and MH17 need to be entered in 1st table and in ontology	12/4/13	Done
11/4/13	Because Inclusion/Exclusion criteria is taken from Statement, rather than Formula (which is not always possible), the criteria are sometimes vague/weak. EG, PS37: Sickness Absence Rate = single layer		Include in Discussion

Date	Issue	Date Resolved	How
15/4/13	Clinical Terminology Code Version needs to be deleted, as its status as a subslot does not accomplish the task intended. It inherits the superslot, but does not allow you to attach a version.	15/4/13	Done
16/4/13	Some slots/widgets are primitive, as they allow (this is sometimes considered necessary to accurately identify the information and make it both searchable and linked as the ability to define Relationships is not as flexible in Protégé as is sometimes needed) you to enter more than one data type. Eg, Clinical Terminology entries include both code and term(s). The complete terminology itself would need to be integrated into the ontology, with a look-up feature.		Include in Discussion
17/4/13	Nd to add Related Indicators for CA25 (Quality of Patient Experience: percentage compliance with [Cancer] patient experience measures)	22/5/13	Done. Created query for Patient Experience Dimension
24/4/13	UMLS same gives separate codes for concepts that are essentially the same (eg, C0514823 Provide for privacy and confidentiality, C0515043 Provide privacy and ensure confidentiality). Key word searching of UMLS is cumbersome, requiring entry of synonyms and different versions of same concept.		Include in Discussion

Date	Issue	Date Resolved	How
25/4/13	Need to replace Patient and Coronary Heart Disease codes with C0451606 CHD monitoring for most QOF CHD entries (already have in QOF CHD 9).	22/5/13	Done
26/4/13	Cite Clinical Quality eMeasure Logic and Implementation Guidance v1.3, http://cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Downloads/2014_eCQM_Measure_Logic_Guidancev13_April2013.pdf, https://vsac.nlm.nih.gov/# (Value Set Authority Center), http://www.qualityforum.org/QualityDataModel.aspx ("The Quality Data Model (QDM) is an "information model" that clearly defines concepts used in quality measures and clinical care and is intended to enable automation of electronic health record (EHR) use." – Saved model to HD, including preference rules, p 7) and other links from http://www.nlm.nih.gov/news/nlm_vsac_publishes_annual_update.html in Discussion	5/13	Done
26/4/13	Look at slides and watch video, http://www.qualityforum.org/Calendar/2012/09/Knowledge_Infrastructure_Behind_the_Measure_Authoring_Tool_(MAT).aspx	26/4/13	Looked at slides. Not v useful.

Date	Issue	Date Resolved	How
26/4/13	Difficulties with coding include lack of medical expertise. Can't remember norms for clinical conditions (eg, blood pressure and cholesterol). This makes it difficult to select relevant codes for measurements. Also, some indicator text is non-specific. Eg, QOF DM 23 (or equivalent test/reference range depending on local laboratory) Some ranges specified in indicators do not show as an option in UMLS, requiring general codes that result in the same coding for different indicators (Eg, aged 53-70 - VSA09)		Include in Discussion

Appendix 7 Classes and Subclasses

A class is “ concept in the domain of the ontology (Musen et al. 2012).

Classes may have subclasses, which inherit the properties or attributes of their parent versions.

Class	Subclass	Definition
Dimension		Aspect of quality; identified from (Darzi 2008) UK Department of Health report, collating vision from 10 UK Strategic Health Authorities.
	Effectiveness	This dimension relates to understanding success rates from different treatments for different conditions. It may also extend to people’s well-being and ability to live independent lives.
	Patient Experience	"Quality of care includes quality of caring. This means how personal care is – the compassion, dignity and respect with which patients are treated. It can only be improved by analysing and understanding patient satisfaction with their own experiences." (Darzi 2008)
	Safety	This dimension of quality is that we do no harm to patients. "This means ensuring the environment is safe and clean, reducing avoidable harm such as excessive drug errors or rates of healthcare associated infections." (Darzi 2008).
Next Stage Review Pathway		Clinical pathway, identified from 2008 Darzi DoH report collating vision from 10 UK Strategic Health Authorities
	Acute Care	One of eight clinical areas assigned to NHS Strategic Health Authorities for needs assessment exercise. Darzi 2008 DoH report.
	Children and Young People	One of eight clinical areas assigned to NHS Strategic Health Authorities for needs assessment exercise. Darzi 2008 DoH report.

Class	Subclass	Definition
Next Stage Review Pathway	*End of Life Care*	One of eight clinical areas assigned to NHS Strategic Health Authorities for needs assessment exercise. Darzi 2008 DoH report.
	Long Term Conditions	One of eight clinical areas assigned to NHS Strategic Health Authorities for needs assessment exercise. Darzi 2008 DoH report.
	Maternity and Newborn Care	One of eight clinical areas assigned to NHS Strategic Health Authorities for needs assessment exercise. Darzi 2008 DoH report.
	Mental Health	One of eight clinical areas assigned to NHS Strategic Health Authorities for needs assessment exercise. Darzi 2008 DoH report.
Indicator		Measures healthcare outcomes.
	Formula	Calculation methodology for determining indicator data result
	Inclusion/Exclusion Criteria (subclass to Formula)	The inclusion and exclusion criteria are generally taken from the indicator Statement, due to metadata inconsistencies.
Purpose		Intended application (From Institute of Medicine 1992 classic CPG report (Field and Lohr 1992), referred to as "Guidelines by Purpose"; in this case 'Indicators' substitutes for 'Guidelines').
	Appropriate Use of Specific Technologies and Tests as part of Clinical Care	Eg, Use of autologous or donor blood for transfusions.
	Diagnosis and Prediagnosis Management of Patients	Eg, Management of patients following coronary-artery bypass graft
	Indications for Use of Surgical Procedures	Eg, Indications for carotid endarterectomy.
	Screening and Prevention	Eg, Vaccination for pregnant women who are planning international travel

Appendix 8 Slots and Subslots

Properties of classes and subclasses in the ontology are specified as ‘slots’.

Slots may have subslots, which inherit the properties or attributes of their

parent versions.

Class/Subclass	Slot	Subslot	Definition
Indicators	Access Point		Location(s) of results of indicator assessment
Indicators	Clinical Terminology Code		The code(s) and clinical term or terms used to source data to calculate the indicator
Indicators	Creator		Developer(s) or author(s) of the indicator content
Indicators	Formula		Calculation methodology for determining indicator data result
Indicators	Formula	Inclusion/ Exclusion Criteria	This is the parent layer for subslots of inclusion or exclusion criteria.
Indicators	Formula	Exclusion Criteria Full (subslot to Inclusion/ Exclusion Criteria)	Eg, in the previous twelve months
Indicators	Formula	Exclusion Criteria Minus One Layer	Eg, congenital heart disease surgery
Indicators	Formula	Inclusion Criteria Full	Eg, ST-elevation myocardial infarction (STEMI) patients
Indicators	Formula	Inclusion Criteria Minus One Layer	Eg, who received thrombolytic treatment

Class/Subclass	Slot	Subslot	Definition
Indicators	Formula	Inclusion Criteria Minus Two Layers	Eg, within 60 minutes of call (call to needle time)
Indicators	Formula	Inclusion Criteria Minus Three Layers	Eg, who received primary angioplasty
Indicators	Formula	Inclusion Criteria Minus Four Layers	Eg, within 120 minutes of call (call to balloon time)
Indicators	Formula	Inclusion Criteria Minus Five Layers	Similar to other inclusion layers.
Indicators	Indicator Statement		A sentence or paragraph clearly describing what is being measured [referred to as “Detailed Descriptor” by NHS Information Centre]. The statement is sometimes taken from sources other than Detailed Descriptor, due to issues of consistency and clarity.
Indicators	Is Broader Than		Shows indicator is broader than (an)other indicator(s)
Indicators	Is Narrower Than		Shows indicator is narrower than (an)other indicator(s)
Indicators	Is Related To		Shows indicators can be related at the same level (neither broader nor narrower
Indicators	Next Stage Review Pathway		Complex value type per AMIA 2003 Protege tutorial slide, Common Facets: Value Type, where a slot may be an instance of another class. Indicators may be categorised by Next Stage Review pathways, Purpose, and Dimensions.
Indicators	Notes		Miscellaneous information to support the organisation and referencing of quality indicators.

Class/Subclass	Slot	Subslot	Definition
Indicators	Number of Layers of Exclusion Criteria		This is to support development of queries for specific layers of exclusion criteria.
Indicators	Number of Layers of Inclusion Criteria		This is to support development of queries for specific layers of inclusion criteria.
Indicators	Publisher		Party responsible for making indicator available
Indicators	Purpose		from Institute of Medicine 1992 classic CPG report (Field and Lohr 1992), referred to as "Guidelines by Purpose"; in this case 'Indicators' substitutes for 'Guidelines' Screening and prevention: Eg, Vaccination for pregnant women who are planning international travel. [3rd Broadest, 3-way tie] Diagnosis and prediagnosis management of patients: Eg, Evaluation of chest pain in the emergency room. [3rd Broadest, 3-way tie] Tends to be paired with Appropriate use of technologies Indications for use of surgical procedures: Eg, Indications for carotid endarterectomy. [3rd Broadest, 3-way tie] Appropriate use of specific technologies and tests as part of clinical care: Eg, Use of autologous or donor blood for transfusions. [2nd Broadest] Tends to be paired with Diagnoses and prediagnosis management Guidelines for care of clinical conditions: Eg, Management of patients following coronary-artery bypass graft [Broadest]”
Indicators	Reference		The source(s) from which the indicator has been derived; normally the dataset applied (eg, National Audit dataset)
Indicators	Unique Identifier		Unambiguous reference number or string of letters and/or numbers
Indicators	URL		URL with most detail about methodology

Class/Subclass	Slot	Subslot	Definition
Indicators	Version History		Record of revisions to the indicator
Dimension/ Effectiveness	Complication Rates		Intended to show success of treatments for different conditions. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Effectiveness	Mortality Rates		Intended to show success of treatments for different conditions. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Class/Subclass	Slot	Subslot	Definition
Dimension/ Effectiveness	Proms		Patient-Reported Outcomes Measures. Examples include improvement in pain-free movement after a joint replacement, or returning to work after treatment for depression. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Effectiveness	Survival Rates		Intended to show success of treatments for different conditions. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Patient Experience	Compassion		Patient satisfaction with how personal care is. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Patient Experience	Dignity		Patient satisfaction with how personal care is. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Patient Experience	Respect		Patient satisfaction with how personal care is. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf

Class/Subclass	Slot	Subslot	Definition
Dimension/ Safety	Cleanliness		The first dimension of quality must be that we do no harm to patients. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Safety	Drug Errors		The first dimension of quality must be that we do no harm to patients. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf
Dimension/ Safety	Healthcare-Related Infections		The first dimension of quality must be that we do no harm to patients. Darzi 2008 DoH report. http://www.official-documents.gov.uk/document/cm74/7432/7432.pdf

Appendix 9 The Ontology

The ontology can be found in the CD attached to the back of this thesis. You will need to install Protégé Frames 3.4.1 (Stanford Center for Biomedical Informatics Research 2014b).

After you have installed Protégé 3.4.1, you can ask it to open a project. You will need to have inserted the attached CD into your computer. Select Open Other, then the Pilot Ontology folder and the Protégé 3.4.1 folder. Then select the NHS Quality Indicators Ontology pprj file.

Once you have opened the ontology, click cancel on the pop-up window that asks you to Choose an associated ChAO. Then click Close on the pop-up window that says No ChAO. The default screen shows the classes in the left frame. Click the triangle next to each class to view subclasses. There are tabs towards the top of the screen, above the frames, to view Slots, Forms, Instances and Queries. Subslots can be viewed if a triangle is to the left

Instances have been entered for the Indicators class. Click on Indicator in the left frame and an Instance Browser frame will appear in the middle of the screen, showing unique identifiers for all 222 indicators. Click on one of the unique identifiers and its properties (slots) will appear in the right-hand frame.

Queries to find Instances of the indicators with common criteria may be entered by clicking the Queries tab. Click on the rectangles with + signs above the text boxes for Classes and Slots to select criteria. Enter free text in the

String text box to specify additional criteria. You may also select a sample query from the Query Library in the frame at the bottom of the screen. To execute a sample query, click on the middle button at the top of that frame, on the right side. Then click the Find button in the bottom right corner of the Query frame. Search results will appear on the right side of the screen.