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Towards business intelligence in preoperative care:

Choice, chance and communication

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A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy in Information Systems

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Abstract

BACKGROUND Each year millions of patients worldwide undergo elective surgery to correct a non-life-threatening health condition. For most patients, the risks of surgery and anaesthesia are low, however complications following surgery are an important cause of death. Determining the risk of death or disability is often the remit of the anaesthetist, so accurate information about these risks is needed during the preoperative anaesthetic assessment if informed decisions are to be made. There are limited data about the risk of dying that are relevant to the anaesthetist’s own clinical setting and, as a result, the risks of surgery can be poorly estimated and communicated. The application of routinely collected data (RCD) and business intelligence (BI) may provide anaesthetists with valuable information about perioperative outcomes, and in doing so, further improve the process of shared surgical decision-making during the preoperative assessment.

AIM Using RCD, this pragmatic and interpretive study sought to gain actionable insights into perioperative outcomes for patients coming forward for elective surgery and to make these insights available to anaesthetists to support shared decision-making during the preoperative assessment.

METHOD A two-year participatory action research (PAR) study was conducted in the Department of Anaesthesia and Perioperative Medicine at Auckland City Hospital, New Zealand. The first of three PAR cycles was undertaken to investigate the appropriateness of an information systems development (ISD) methodology, Multiview2, to inform the development of a BI prototype in the healthcare sector. The second PAR cycle used qualitative interviews with specialist anaesthetists to explore the work of risk communication during the preoperative assessment. The third PAR cycle conducted a single-centre, retrospective cohort study to describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. The mixed and varied nature of these cycles reflected the interdisciplinary nature of the research.

FINDINGS Over the course of the three PAR cycles, the objectives of this study were investigated. First, the stereotypical roles and outcomes for BI development were elicited, which led to a revised Multiview2 framework that is considered appropriate for BI development in the healthcare sector. Second, the interactional and circumstantial influences on anaesthetists’ communications with patients, as part of the shared decision-making that occurs prior to surgery, were found to be varied and complex. Third, 30-day and 1-year
perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012 were found to be comparable to those published internationally. Throughout these research cycles and through the building of a BI prototype, this research shows how one might go about using RCD to provide actionable insights into perioperative outcomes, and how the Multiview2 methodology, with its emphasis on the social and technical aspects of ISD, can be used to support that journey.

**CONCLUSIONS** Shared decision-making and early discussion of the risks, benefits and alternatives to surgery are required to help patients to make the choices about surgery and anaesthesia that best meet their needs. This research has shown that RCD can be used to provide anaesthetists with valuable insights about patient outcomes that are relevant to their own clinical setting to support risk benefit assessment before elective surgery. The BI journey to acquiring these insights requires a unique mix of organisational analysis, sociotechnical analysis, data modelling and technical development and can be facilitated by the Multiview2 methodology. Choice, chance and communication lie at the heart of patient-centred preoperative care, and therefore the value of accurate, timely and relevant information about perioperative outcomes that are derived from RCD and BI should not be underestimated.
Acknowledgements

To my husband, best friend and soul mate, Keagan, we have always done everything together and this thesis has been no exception. You have supported me through the late nights, including those that became early mornings, and for this I am eternally grateful. This thesis is dedicated to you.

To my parents, Paul and Judy, and my siblings Rachel, Nicola and Daniel, thank you for your words of encouragement and your continuing optimism over the course of this journey. Without your constant questioning about how much more I had to do to complete, I may never have made it through to “the other side”.

To my friends who all encouraged me to see this through to the end, thank you for your unwavering belief in my ability to write constructively and to think critically. I look forward to catching up again soon, sans thesis-in-progress of course!

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**Glossary of terms**

**anaesthesia**  
The practice of administering medications to induce temporary loss of sensation and/or awareness, which allows surgery to proceed without causing undue discomfort or distress [1].

**anaesthetist**  
A specialist doctor who provides medical care to patients at, during or around the time of surgery, including preoperative assessment, provision of sedation and anaesthesia during surgery and management of postoperative pain.

**business intelligence**  
“The continuous processes for transforming data into useful information; the technologies used to support these processes and the knowledge gained through human analysis and interpretation of the resultant information” [2 p. 180].

**District Health Board**  
An organisation responsible for providing or funding health and disability services to populations within a defined geographical area [3].

**health information system**  
“A system to collect, process, store, transmit, and/or display [health] information” [4, p.3]

**information systems development**  
The act of developing an information system, usually with emphasis on the methodologies and processes used to do so.

**Multiview**  
A framework and methodology that informs the emergence of a contingent and holistic approach to information systems development.

**NHI number**  
A unique number that is used to identify individuals who use health and disability support services in New Zealand [5].
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>participatory action research</td>
<td>A cyclical form of research in which people in an organisation of interest participate actively with the researcher to gather or generate data in order to learn iteratively [6].</td>
</tr>
<tr>
<td>perioperative</td>
<td>(Of a process or treatment) occurring or performed at or around the time of surgery. The term is typically used to refer to the period of time extending from when the patient attends their first surgical assessment until the time the patient is discharged from hospital.</td>
</tr>
<tr>
<td>Routinely collected data</td>
<td>Clinical and sociodemographic data that are gathered outside of the research setting as part of routine patient care. These data are increasingly stored and accessed electronically for secondary use.</td>
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**List of abbreviations**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AAC</td>
<td>Anaesthetic Assessment Clinic</td>
</tr>
<tr>
<td>ACC/AHA</td>
<td>American College of Cardiology/American Heart Association</td>
</tr>
<tr>
<td>ACHI</td>
<td>Australian Classification of Health Interventions</td>
</tr>
<tr>
<td>ADR</td>
<td>action design research</td>
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<tr>
<td>AIMS</td>
<td>anaesthesia information management system</td>
</tr>
<tr>
<td>AR</td>
<td>action research</td>
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<tr>
<td>ASA</td>
<td>American Society of Anaesthesiologists</td>
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<tr>
<td>AUC</td>
<td>area under the curve</td>
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<tr>
<td>BI</td>
<td>business intelligence</td>
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<tr>
<td>BUPA</td>
<td>British United Provident Association</td>
</tr>
<tr>
<td>CACI</td>
<td>Charlson Age Comorbidity Index</td>
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<tr>
<td>CCI</td>
<td>Charlson Comorbidity Index</td>
</tr>
<tr>
<td>CI</td>
<td>confidence interval</td>
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<tr>
<td>CPR</td>
<td>collaborative practice research</td>
</tr>
<tr>
<td>DAPM</td>
<td>Department of Anaesthesia and Perioperative Medicine</td>
</tr>
<tr>
<td>DAR</td>
<td>Department of Anaesthesia Research</td>
</tr>
<tr>
<td>DHB</td>
<td>District Health Board</td>
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<tr>
<td>DVT</td>
<td>deep vein thrombosis</td>
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<tr>
<td>EBM</td>
<td>evidence-based medicine</td>
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<td>ECG</td>
<td>electrocardiogram</td>
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<td>EHR</td>
<td>electronic health record</td>
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<tr>
<td>ERP</td>
<td>enterprise resource planning</td>
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<tr>
<td>GP</td>
<td>general practitioner</td>
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<tr>
<td>ICD</td>
<td>International Classification of Diseases</td>
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<tr>
<td>ICT</td>
<td>information and communications technology</td>
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<tr>
<td>ICU</td>
<td>intensive care unit</td>
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<tr>
<td>IS</td>
<td>information systems</td>
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ISD  information systems development
IT   information technology
HIS  health information system
LHS  learning healthcare system
MI   myocardial infarction
NAM  National Academy of Medicine
NCEPOD National Confidential Enquiry into Patient Outcome and Death
NHI  National Health Index
NSQIP National Surgical Quality Improvement Program
NZ   New Zealand
ORDA Operating Room Day of Admission
PACU Post Anaesthesia Care Unit
PAR  participatory action research
PAS  patient administration system
PE   pulmonary embolism
PIMS perioperative information management system
POMRC Perioperative Mortality Review Committee
RCD  routinely collected data
RCRI Revised Cardiac Risk Index
RCT  randomised controlled trial
S2T  source to target
SQL  Structured Query Language
SRS  Surgical Risk Score
SSM  soft systems methodology
UK   United Kingdom
UM   Unified Modeling Language
US   United States
Chapter 1: Introduction

The care of patients undergoing surgery is being increasingly transformed by the application of ubiquitous information technology (IT). From the anaesthesia machine to the physiologic monitors in the recovery room, IT collects and displays demographic and clinical information in real time across thousands of operating rooms worldwide. Yet, the accumulation of these data is fast outpacing the capacity of healthcare institutions to use the information to improve the efficiency, cost-effectiveness, quality and safety of patient care [7].

This thesis answers the call to action to transform healthcare data into informed insights. Together with members of staff from the Department of Anaesthesia and Perioperative Medicine (DAPM) at Auckland City Hospital, I have used participatory action research (PAR) to explore the application of business intelligence (BI) in the context of risk assessment for patients undergoing elective surgery. In the subsections that follow, the thesis is positioned at the intersection between health and information sciences; the themes that underpin this research are summarised; the nature and significance of the research problem is explained; and the structure for the remainder of the thesis is presented.

1.1 Setting the scene: Health, healthcare and medical informatics

This is an interdisciplinary thesis that is positioned at the intersection of the disciplines of anaesthesia and information systems. Based on the work of Choi and Pak [8], research can be considered interdisciplinary if it meets several criteria. First, the research involves two, and only two disciplines, where the focus is on the reciprocal action of the two disciplines. Second, research participants learn about and from each other, rather than simply about each other. Third, participants have shared goals rather than individual goals in different professions. Fourth, members of different disciplines work jointly on the research, rather than independently on different aspects of the same project. It follows that interdisciplinary research seeks “to analyse, synthesise and harmonize links between disciplines into a coordinated whole” [8, p.359].

This thesis meets each of the criteria elicited by Choi and Pak [8]. Throughout the research journey, all participants maintained shared goals (not necessarily shared skills) and sought to learn from one another as they worked jointly on all aspects of the project, whether that be practically or conceptually. This research was every bit about what IS could teach anaesthesia and what anaesthesia could teach IS. It was not a thesis that required little interaction or collaboration across disciplines. Rather, the research participants strived to achieve a new way of working and a shared appreciation and understanding of each other’s work. This is
sufficient to warrant the research being classified as interdisciplinary, rather than single, multi- or transdisciplinary.

As interdisciplinary research positioned at the intersection between the disciplines of anaesthesia and information systems, the term (medical) informatics is used to further define the position of this thesis. The term refers to the “field [of study] that concerns itself with the cognitive, information processing, and communication tasks of medical practice, education and research, including the information science and the technology to support these tasks” [9, p.1114]. But, the reality is not nearly as plain as this definition might suggest. Friedman [10] recognised that, with regard to informatics, the whole was not nearly as great as the sum of the parts, and reasoned that to simply list the competencies required by the field can conceal the whole that these competencies atomistically describe. Instead, he offered three higher-level characterisations of the field. In his article entitled “What Informatics Is and Isn’t”, he argued that informatics should be viewed as: “(1) cross-training between basic informational sciences and an application domain, (2) the relentless pursuit of making people better at what they do, and (3) a field encompassing four related types of activities” [10, p.224]; that is, model formulation, system development, system deployment and study of effects.

Friedman’s conception of the field represents an important step towards clarifying the meaning of the term informatics. Drawing on his work and my own professional observations, I suggest that medical informatics is more than the location in discipline space where the health and information sciences converge. Rather, the discipline is a true meeting place in every sense of the word. It is a forum that welcomes clinicians, non-clinicians and those “special people” who are almost always “technical and something” [11, p.134]. It is a discipline that is as broad as it is deep, concerned with how clinical knowledge is created, shaped, shared and applied on the one hand, and with how we organise ourselves, both patients and professionals, to enhance the delivery of patient care on the other [12]. It “is not merely a field of study, but a transformational profession in health and health care” [13, p.855].

To do justice to Friedman’s conception of informatics, this thesis needs to provide a good grounding in many of the aspects of anaesthesia care. For this reason, the literature review (and the thesis at large) has canvassed subjects including preoperative anaesthesia assessment, risk assessment and communication and more generally evidence-based medicine (EBM). The subsections that follow provide the reader with insight into the nature of the research problem and the themes that underpin the research, beginning with a conception of elective surgery in New Zealand (NZ).
1.2 Elective surgery in NZ

Surgery is defined as the treatment of injuries or disorders of the body by incision or manipulation with instruments [14]. Patients may undergo surgery to correct a non-life-threatening condition, to aid or confirm a diagnosis or to improve their physical appearance. Surgery commonly falls into two categories of urgency: elective and emergency (acute). Whereas emergency surgery is performed immediately to save life and limb, elective surgery is performed to improve the quality of life of patients suffering from significant medical conditions that do not require immediate treatment [15]. More than 150,000 patients underwent elective surgery at publicly funded hospitals throughout NZ between July 2015 and June 2016 [16], and this figure is set to increase under the government’s national target for improved access to elective surgery [17]. As demand for elective surgery continues to rise, the care of patients undergoing this type of surgery becomes increasingly important and is an area ripe for innovative research.

1.2.1 Patient pathways for elective surgery in NZ

The process of undergoing elective surgery in NZ includes the delivery of patient care before (preoperatively), during (intraoperatively) and after (postoperatively) surgery. Together, these three phases of care are termed perioperative care (Figure 1). At a broad level, perioperative care includes clinical assessment of the patient before surgery, admission to hospital, anaesthesia, surgery and recovery. Clinical care is delivered in hospitals and outpatient clinics by a broad range of healthcare professionals [18] with the aim of improving outcomes for all patients who undergo surgery [19].

![Figure 1](image_url)

**Figure 1.** The components of perioperative care.

At a more detailed level, the process begins in the preoperative period when a general practitioner (GP) refers a patient for surgical assessment and ends in the postoperative period
when the patient is discharged from hospital and returned to the care of their GP. The typical pathway for a patient undergoing elective surgery is depicted in Figure 2. The following description of the pathway is typical of the process at many hospitals throughout NZ. There are many alternate and exception flows for this process. For example, the patient may elect to undergo surgery with a private service provider or may become acutely unwell and require emergency surgery. For the sake of simplicity, these potentialities are not represented in the diagram.

The first step to undergoing elective surgery occurs when a GP refers a patient to a District Health Board (DHB) to be assessed by a consultant (specialist) [15]. Consultant surgeons review all referrals to determine priority based on the information provided by the GP and will arrange for the patient to be seen at the surgical outpatient clinic. This appointment is known as the first specialist assessment and typically occurs within 4 months of the referral being received by the hospital [15]. At the appointment, a member of the surgical team will diagnose the patient on the basis of a physical examination, documented medical history and findings from clinical investigations such as blood tests and X-rays [20]. If surgery is advised to treat the patient’s condition, the patient’s name will be added to the elective services waiting list which is ordered according to the urgency and severity of their condition [20].

Figure 2. The patient pathway to undergoing elective surgery.

Patients are required to attend the outpatient clinic again as part of a preadmission process. This process involves junior medical staff working together with other clinicians including anaesthetists, pharmacists, nurses and physiotherapists to confirm that surgery is still indicated for treatment of the patient’s condition and to ensure that the patient is well enough to undergo the surgery [21]. All adult patients scheduled for elective surgery are required to attend an appointment with an anaesthetist for a preoperative anaesthetic assessment at the
outpatient clinic [22]. Most patients are seen well in advance of their scheduled surgery to give them time to formulate questions about the upcoming procedure.

Patients are sent a preoperative health questionnaire to complete prior to attending their anaesthetic assessment appointment. Upon receipt of the completed questionnaire, an anaesthetic clinic nurse allocates patients to either a 15-minute preoperative anaesthetic assessment or a 1-hour full anaesthetic assessment according to a set of guidelines [22]. The patient is booked into the clinic and will receive a letter explaining when and where to attend. At the anaesthetic clinic, patients are seen by an anaesthetist, assessed for their suitability for various forms of anaesthesia and given appropriate information about the type of anaesthesia for the surgery they are scheduled for [22]. Patients do not meet their allocated, procedural anaesthetist until the day of their surgery prior to going into the operating room.

On the day of surgery, the procedural anaesthetist refers to the documentation and discussions between the clinic anaesthetist and the patient. He or she discusses the possible anaesthetic techniques and associated risks and benefits and the patient’s preferences. The patient and anaesthetist reach a decision about the anaesthetic technique and the patient gives their written consent to undergo anaesthesia. The patient is taken into the operating room and the anaesthetist starts the anaesthetic once the surgical and nursing teams have all completed the necessary preoperative checks. The anaesthetist remains present during surgery to monitor the patient and ensure they are pain free. Once the surgery is complete, the patient is transferred to the recovery room/post anaesthesia care unit (PACU) and further monitored to ensure that they are in a stable condition. Most patients will spend up to an hour in the PACU prior to being returned to the hospital ward [22]. Once the surgical team have established that the patient has met the criteria for discharge, the patient is discharged from hospital and returned to the care of their GP. The patient is required to attend a follow-up appointment with a member of the surgical team, typically within six weeks postoperatively, to complete the usual patient pathway for elective surgery.

1.3 Background literature

In the preceding subsections, I introduced the concept of surgery and outlined the delivery of pre-, intra- and postoperative care specifically for patients undergoing elective surgery in NZ. To build on this understanding, the background literature relevant to the research problem is summarised in the subsections that follow. This research explores the intersection of three large and important research domains – preoperative care, risk assessment and communication, and BI. The themes that underpin the research are explored at the intersection
between pairs of these research domains (Figure 3). First, the subject of preoperative assessment for patients undergoing elective surgery is summarised in subsection 1.3.1. Second, the literature on risk assessment and communication in the period before surgery is appraised in subsections 1.3.2 and 1.3.3. Finally, the literature on BI is reviewed in section 1.3.4. In this final section, the potential for use of existing healthcare data to support improved preoperative care is considered.

![Figure 3. Thesis domain – the intersection between preoperative care, risk assessment and communication, and BI.](image)

### 1.3.1 Why is preoperative anaesthetic assessment important?

Outpatient preoperative assessment by an anaesthetist is an important component of the care a patient receives before surgery (Figure 4). The goals of the assessment are threefold: (1) to evaluate medical conditions or factors that may increase the risk of complications, (2) to optimise these conditions or factors before surgery with the aim of reducing this risk, and (3) to estimate and communicate total (overall) risk to the patient [23-26]. As part of the assessment, the anaesthetist will conduct an interview and physical examination of the patient, a review of previous medical, surgical and anaesthesia problems, a detailed account of current medication use, and will make provisions for obtaining and reviewing preoperative tests and recommendations from subspecialty consultations [24]. The findings from these investigations are documented in the patient’s medical record and are used to help assess the likelihood of perioperative complications, optimise pre-existing medical conditions, develop
an appropriate perioperative care plan, to educate the patient about surgery and anaesthesia [27], and ultimately, to assist patients to make the choices about surgery and anaesthesia that best meet their needs.

![Diagram showing preoperative, intraoperative, and postoperative care](image)

**Figure 4.** The place of preoperative assessment before surgery.

Both surgeon and anaesthetist play an important role in preparing patients for surgery, but the scope of this thesis is limited to preoperative assessment by an anaesthetist. Anaesthetists play a key role in minimising avoidable harm after surgery, so they are uniquely positioned to fulfil unmet need in the care of the surgical patient [28]. The reasons for this are twofold. First, the growing emphasis on reducing modifiable risk has seen the role of the anaesthetist expand beyond the provision of sedation and anaesthesia in the operating room [28, 29]. Many patients coming forward for surgery are older and have more long-term medical conditions so they are likely to be at higher risk of suffering from complications of surgery. Early identification and mitigation of surgical risk has been shown to improve patient outcomes [30, 31], so the anaesthetist’s role in coordinating and planning patient care ahead of time is an increasingly important one. Second, the move towards shared decision-making based on patient choice and preference [29] has seen increased emphasis on estimating and communicating perioperative risk to patients [26]. An integral part of the decision to undergo surgery is the provision of understandable information to patients about the risks and benefits of surgery and alternative treatments. Early discussion of perioperative risk may be especially valuable for patients deciding whether to undergo procedures where the benefits are small, uncertain or need to be closely balanced against the risks [32]. Indeed, some patients may choose to forego surgery or pursue less invasive alternatives after being informed of the likely risks [33]. Anaesthetists possess a combination of training, skills and experience that sees them uniquely positioned to determine overall perioperative risk and to communicate this risk to patients, so that informed decisions balancing risk and benefit can be made.
1.3.2 Preoperative risk assessment and communication

In the context of preoperative care, risk is defined as the probability that a particular adverse event occurs during the perioperative period or results from undergoing anaesthesia and surgery. Any patient undergoing a surgical procedure is exposed to a small risk of anaesthetic or surgical mishap. Since these events are usually unpredictable, risk is more generally related to patient- and surgery-specific characteristics [34-37]. For example, certain procedures expose patients to unique risks, such as brain damage, as a consequence of intracranial neurosurgery. On the other hand, particular subgroups of patients are at risk for specific complications, for example pneumonia in patients who smoke [38], acute renal failure in patients with pre-existing kidney disease [39], and postoperative delirium and cognitive dysfunction in geriatric patients undergoing surgery [40]. Adverse events that occur after surgery may be attributable to anaesthesia (e.g. dental injuries resulting from tracheal intubation), related to the surgery (e.g. implant failure after hip joint replacement) or might be better attributed to the total epoch of surgery-anaesthesia care (e.g. death after surgery [41]).

Great strides have been made in reducing the likelihood of undesirable postoperative outcomes. However, the complex physiological changes that occur intraoperatively mean that patients are at risk of experiencing at least some adverse outcomes, which range in severity from pain, nausea and vomiting to infection, heart or circulatory problems and even death [42].

Risk assessment and communication is essential for informed, shared decision-making before surgery [43, 44]. In many cases, the decision to proceed to surgery is an obvious one, but sometimes this decision is not straightforward. Patients undergo surgery to increase their length or quality of life [45], but these benefits need to be weighed against the potential harms. Early identification of increased risk assists the patient and anaesthetist to better understand the risk-benefit ratio of a procedure [46]. This information is important because studies have shown that up to one-fifth of potential elective surgeries are rejected by patients who have participated in shared decision-making with early discussions of risk, benefit and expectations [47, 48]. As well as minimising the avoidable harm after surgery, ensuring that patients understand the trade-offs between long-term benefit and upfront risk of death and disability represents a crucial component of shared and informed decision-making and high-quality preoperative care [26].

1.3.3 Routinely collected data in support of preoperative risk assessment

The risks and benefits following surgery are evaluated on the basis of multiple pieces of information. In their assessment of perioperative risk, anaesthetists consider the patient’s
medical conditions, therapies, alternative treatments, surgical and other procedures, and options for anaesthetic techniques [24]. This information is melded with evidence extrapolated from clinical studies, personal experience with previous cases, pathophysiological knowledge, patient preferences for alternative forms of care and convenient heuristics [49-53]. These pieces of information are used to frame discussions about the likelihood of both commonly occurring minor adverse anaesthetic outcomes such as sore throat or nausea and vomiting, and rare but possible major adverse outcomes such as heart attack or death [54].

In estimating the risks and benefits associated with anaesthesia and surgery, anaesthetists may take into account relevant randomised controlled trials (RCTs) and systematic reviews [53]. As the “gold standard” for evaluating the efficacy of therapeutic interventions, evidence from well-executed RCTs is considered the strongest foundation to inform perioperative patient care. However, it can be difficult to understand the extent to which the findings of RCTs can be generalised to everyday clinical practice [55, 56]. Many clinicians struggle to apply new knowledge, since most evidence has been produced by studies involving patients who differ from their own and who were treated in highly controlled research settings [57, 58].

The use of routinely collected data (RCD) stored in a hospital information system (HIS) may represent an adjunct approach to identifying, quantifying and understanding the risks and benefits following surgery and anaesthesia. Although the term is loosely defined (see Crombie [59]), RCD are widely considered to encompass clinical and sociodemographic information from a variety of sources including electronic medical records, administrative data for billing purposes, and sources of sociodemographic data [60] that manifest from everyday interactions between patient and healthcare sector [61]. These are large, population-based datasets that are well suited to the study of real-world differences in patient outcomes [62, 63].

1.3.4 BI and healthcare

Extracting and analysing RCD through the use of BI may provide anaesthetists with a valuable source of generalisable information about the risks following surgery. The term BI first appeared in the seminal work of IBM researcher Luhn in the late 1950s. Luhn [64p. 314] defined business as a “collection of activities carried out for whatever purpose, be it science, technology, commerce, industry, law, government, defence, et cetera”; an intelligence system as “the communication facility serving the conduct of a business (in the broad sense)”; and intelligence as “the ability to apprehend the interrelationships of presented facts in such a way as to guide action towards a desired goal”. Three decades after Luhn, Howard Dresner of the
Gartner Group popularised BI as an umbrella term to “describe concepts and methods to improve business decision-making by using ‘fact-based systems’” [65, para 22].

BI has emerged as an important domain of enquiry for both IT practitioners and researchers, reflecting the size, scale and consequence of data-related problems that plague modern-day organisations [66]. Although the business sector is at the forefront of BI and, more recently, big data application development, the healthcare sector has yet to establish a mature approach to integrating, analysing and leveraging data to derive insight [67]. Healthcare decision-makers and researchers commonly use aggregated data from distributed repositories to garner insight into healthcare practices and to understand and improve patient outcomes and quality of care. Studies have highlighted the benefits of these practices to healthcare organisations, which include improved patient care and outcomes, effective utilisation of human resources [68], improved process efficiency [69] and cost avoidance [70]. However, these analyses tend to be ad hoc and often meaningful information cannot be accessed without manual, time-consuming and potentially expensive intermediary processes [7, 67, 71, 72]. Given the high levels of complexity and nuance in this setting [73], many healthcare organisations have yet to implement BI systems. Those that have embarked on the BI journey have discovered that there is a paucity of research to guide BI systems development and implementation [74]. However, with the growing number and sophistication of healthcare technologies, the issue of how well healthcare data are used to support evidence-based decision-making has become increasingly important and is an area ripe for innovative research.

1.4 Overview of the research problem

The research problem of this thesis is situated at the intersection of the domains of preoperative care, risk assessment and communication and BI. Dr Doug Campbell and I set out to address this problem, which can be described as follows:

_The current business intelligence capability in preoperative care does not provide anaesthetists with sufficient, actionable insights relevant to their own clinical settings in support of risk-benefit assessment before elective surgery._

To address this problem, we initiated a project to develop a BI prototype for use in preoperative care. The aim of the project was twofold: (1) to gain actionable insights into perioperative outcomes for patients undergoing elective surgery in the care system that generated the data, and (2) to make these insights available to anaesthetists at the point of care to support risk-benefit assessment and communication for shared surgical decision-making during the preoperative assessment. In keeping with the interdisciplinary nature of medical
informatics, the objectives of the research sought value for both anaesthetists and IT practitioners working in the BI space.

The objectives of the research were:

1. To investigate the appropriateness of an information systems development (ISD) methodology, namely Multiview2, to inform the development of a BI prototype in the healthcare sector. There is a paucity of evidence to guide BI development and so a web development methodology was chosen to expand the body of literature in this space. The features of Multiview2, specifically its support for development that is contingent, even-handed and situated, mean the approach is well suited to early development efforts such as BI prototypes in healthcare.

2. To explore how the work of risk assessment and communication during the preoperative anaesthetic assessment is achieved.

3. To describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. This objective allowed us to make an assessment as to the value of this information for use in preoperative risk assessment and communication.

The research was expected to contribute toward a better understanding of how one might go about using RCD to provide actionable insights into perioperative outcomes, what that journey could look like and how the Multiview2 methodology, with its emphasis on the social and technical aspects of development, can be used to support that journey.

The methods used to address the research problem are summarised in the following subsection and the research we performed to meet these objectives during the development of a BI prototype over a two-year period is presented in subsequent chapters.

1.5 Overview of the research design

Action research (AR), and more specifically participatory action research (PAR) was the method of enquiry adopted for this research. AR is widely defined as a process of enquiry that

*aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework* [75, p.499]

Development of the AR method is often credited to Kurt Lewin [76, 77], a social and experimental psychologist who combined theory, practice and change to study social
psychology within the framework of field theory in the mid-1940s [78-80]. PAR is one of several forms of AR that have emerged since that time. Whyte and colleagues define PAR as an approach in which

... some of the people in the organization or community under study participate actively with the professional researcher throughout the research process from the initial design to the final presentation of results and discussion of their action implications. [6, p.20]

Lewin, along with most subsequent researchers, have conceived of AR as a cyclical two-stage process of action and reflection.

Our PAR process for this thesis can be described as follows (Figure 5). Three iterative cycles of PAR, each successively building upon the learnings reaped from earlier cycles, were undertaken. Each PAR cycle was composed of five steps, namely diagnosing, action planning, action taking, evaluating and specifying learning.

In the first cycle, we developed a small BI prototype in keeping with the tenets of the Multiview2 ISD methodology to elicit information about perioperative outcomes. As a prototype, the goal was to provide anaesthetists with information about perioperative outcomes as early on in the project as possible. We recognised that the development was likely to require significant data discovery efforts, so we made the choice to focus on the assessment of data quality at the outset. If the data quality could not be assured then any work to conceptualise the work of risk communication might be considered less meaningful. The first PAR cycle manifested our limited knowledge of the methods anaesthetists use to assess and estimate the risks and benefits of surgery and to communicate this information to patients.

In the second cycle, we focused on the sociotechnical aspects of the ISD. We explored how the work of risk assessment and communication is achieved during the preoperative anaesthetic assessment with a view to using this information to guide future development. Having constructed a conceptualisation of the work of risk communication, we turned our attention to what the data could tell us about perioperative mortality at our institution and how this might compare to the international literature.

In the third PAR cycle, we used quantitative methods to describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. This cycle was needed in order to make an assessment as to the value of this information for use in preoperative risk assessment and communication.
Throughout each cycle, we sought evidence to confirm whether our concepts were appropriate, and using reflection we conceptualised and generalised what happened (action). Multiple methods for data collection and data analysis were used to collect and analyse data within changing contexts and time periods as the PAR process iteratively progressed.

Figure 5. Approach to PAR for this thesis.

1.6 The research context and the action researcher

The knowledge gained through the PAR cycles is “situated” insofar as it is concerned with producing local, actionable knowledge by focusing on a problem in a particular context [81]. For this reason, it is important that the reader is made aware of the research context, the role of the action researcher, and, more generally, how the research problem came into being. To this end, the following subsection describes the research context, outlines my role as a PhD
student and clinical research analyst within the Department of Anaesthesia Research (DAR) at Auckland City Hospital, and describes the origins of the research problem.

This thesis was carried out in DAPM at Auckland City Hospital within Auckland DHB (Figure 6). Auckland DHB is NZ’s largest healthcare provider and is responsible for the provision of publicly funded emergency, medical, surgical, community health and mental health services to a local catchment of almost 500,000 people [82]. Emergency medical and emergency or elective surgical services for adult patients are delivered at Auckland City Hospital; equivalent services for children are delivered at Starship Children’s Hospital; and outpatient services and day-stay surgeries are performed at the Greenlane Clinical Centre. Auckland City Hospital is a 1,200-bed, university affiliated, tertiary facility and is the largest of the three sites. The hospital provides more than 20,000 elective surgical discharges per year, making it NZ’s largest healthcare and clinical research facility [21]. The Greenlane Clinical Centre is a comparatively relaxed environment, with patients visiting by appointment [83]. Preoperative assessment and follow-up clinics for surgical specialties and adult, obstetric and gynaecology anaesthesia operate daily at this site [22]. All adult patients coming forward for elective surgery are seen by an anaesthetist at the Greenlane Clinical Centre for their preoperative anaesthetic assessment before surgery.

![Auckland District Health Board (ADHB)](image)

**Figure 6.** The research setting.

The provision of pre-, intra- and postoperative anaesthesia care for adult patients undergoing surgery at Auckland City Hospital is provided by DAPM. Anaesthesia services are provided for patients undergoing emergency or elective neurological, vascular, urological, general and
orthopaedic surgery across 11 elective and two emergency operating rooms on Level 8 of Auckland City Hospital. Anaesthetists in the department are involved in all aspects of patient care, from assessing patients’ health prior to surgery at the Anaesthetic Assessment Clinic (AAC) based at Greenlane Clinical Centre and on the wards at Auckland City Hospital to providing anaesthesia in the operating rooms and managing patients’ pain after surgery. The department employs 55 consultant anaesthetists who are supported by 25 junior doctors to provide anaesthesia care to more than 10,000 patients per year.

In addition to the provision of clinical care, Auckland City Hospital also has a strong research focus. DAR is located within DAPM. The department has a small team comprising research assistants, nurses, analysts and fellows, all of whom report to the Director of Anaesthetic Research. The department assumes responsibility for the coordination of anaesthetist and industry-initiated clinical studies that seek to improve the care of patients undergoing surgery and anaesthesia.

With a background in pharmacology, I was employed by DAR for three years as a clinical research analyst to support a number of anaesthetist- and industry-initiated studies. During this time, I was responsible for identification of suitable patients for inclusion in clinical trials, gaining informed consent from patients, and subsequent follow-up of patients through to completion of the trial protocol. These functions required me to liaise with wards, theatres, pharmacy, anaesthetic and surgical staff, and patients and their caregivers. Through my work I also acquired an understanding of how clinical care was represented across the HIS. It was necessary to review patients’ demographic information and medical history, including laboratory results, diagnostic tests and records of previous anaesthetic and surgical events to determine whether they were eligible to participate in a clinical trial. After a patient gave their consent to participate in a trial, I was required to record information about their intraoperative and postoperative course, including whether the patient had suffered any complications. To complete the necessary documentation, I visited patients in person in the recovery room (PACU) and the Department of Critical Care Medicine (ICU) and on the wards; consulted their paper and electronic medical records and liaised with their doctors, nurses and caregivers. Although I am not an anaesthetist, my varied role saw me become familiar with the people, jargon, systems, processes and practices of a number of the hospital services that were responsible for the care of patients undergoing surgery.

The research problem arose from informal conversations with consultant anaesthetist Dr Doug Campbell concerning the absence of readily available data on perioperative outcomes at Auckland City Hospital at the time. Dr Campbell is a long-standing member of staff in
DAPM. In addition to his role as a consultant anaesthetist, he has a central and active role as co-investigator on several large multicentre trials of anaesthesia and postoperative outcomes that are run through DAR. We were colleagues and I would often recruit patients into studies for which he was either the lead investigator or a co-investigator. Dr Campbell was one of the “go-to” anaesthetists for research in the department. I could call on him whenever I needed clarification as to whether a patient was eligible to participate in a clinical trial, whenever a patient had further questions about a clinical study that I was unable to answer, or when I needed a doctor to prescribe clinical trial medicines for a patient or obtain informed consent from a patient for a study. He has significant experience in adult and emergency anaesthesia, having trained in both the United Kingdom (UK) and NZ before completing his vocational training in August 1999.

As we went about our work, the subject of using HISs to explore perioperative outcomes at Auckland City Hospital would often come up in conversation. We talked about how data on perioperative outcomes specific to the cohort of patients cared for at the institution were largely invisible to anaesthetists during the preoperative assessment. We talked about the difficulties inherent in extrapolating from international research to local patient populations, particularly as they relate to the discussion of the risks and benefits of surgery. We also talked about the need for “local” risk information that could be used by anaesthetists to help patients to come to appropriate decisions about undergoing surgery. Dr Campbell believed that both patients and anaesthetists stood to benefit from access to geographically and temporally relevant data about outcomes for patients undergoing surgery, especially because mortality after surgery was likely to be higher than most clinicians’ estimates. It was the following comment during one of these informal conversations in 2011 which ultimately sparked the research problem that is the subject of this thesis:

*Toyota can tell me how many cars they’ve made and I can’t tell you how many of our patients have died after surgery.* (Informal conversation with Dr Campbell, 2011)

Following this conversation, we decided to see if we could solve this problem whilst at the same time allowing me to complete a PhD thesis. Dr Campbell agreed to be part of my supervision team, and together with mentorship from an external software developer, we set out to use RCD to deliver meaningful information about perioperative outcomes that anaesthetists could use to support their discussions with patients about the risks and benefits of undergoing surgery and anaesthesia.
The research problem gave me leave to combine my knowledge of hospital systems and processes for surgery and anaesthesia with my passion for problem solving and “change through doing” in the context of healthcare. I have worked in both primary and tertiary care, in both computer- and patient-facing roles, and have long subscribed to the idea of organisational change through participation. Those who know me well would describe me as someone who likes to understand and improve processes by changing them. I relish the challenge of solving a complex problem and am usually the one in the room asking “Can we do it differently?” It was important to me that my PhD thesis should reflect these values. The PAR method of enquiry epitomises the idea of research as a social process of gathering knowledge and requires the researcher to work with people to take actions to improve the situation. As a research method, PAR gave me leave to work with others to solve a practical problem in a setting that I was already familiar with, and, in doing so, make a dual contribution to practice and scientific knowledge.

1.7 The structure of the thesis

Having orientated the reader towards the research problem and supporting literature, this chapter now outlines the remainder of the thesis. In Chapter 2: Literature Review, the themes that underpin the research journey are presented. I will explore in more detail the delivery of care for patients undergoing surgery with a focus on the role of the anaesthetist and the preoperative anaesthetic assessment. The chapter then examines the concept of risk assessment and communication as it applies to patients coming forward for elective surgery. This section includes an overview of the current tools and scoring systems available to anaesthetists for this purpose. Lastly, the chapter reviews the current position of BI, particularly as it relates to the healthcare sector and its potential to improve outcomes for patients undergoing surgery.

In Chapter 3: Research Design, the pragmatic and interpretive stance for this research is justified by ontological and epistemological assumptions. PAR is presented as the method of enquiry. The three PAR cycles, each comprising of an action component and a reflection component, are outlined. The processes for data collection, including the use of the semistructured interview and data analysis throughout these cycles, are also detailed. The chapter concludes with a summary of the practices and procedures that were employed to ensure a rigorous approach to this research.

In Chapter 4: Findings: Building a BI Prototype, I present the work that Dr Campbell and I undertook in the organisational analysis, information modelling and software development
quadrants of the Multiview2 methodology to build a BI prototype. This chapter addresses the first objective of this thesis: to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in the healthcare sector.

In Chapter 5: Exploring the Work of Risk Communication, the research focus shifts to the sociotechnical quadrant of the Multiview2 methodology with an emphasis on how work “gets done” during the preoperative anaesthetic assessment. “Work” in this context refers to the assessment and communication of the risks and benefits of undergoing anaesthesia and surgery, and was explored through use of semistructured interviews with clinic anaesthetists. This chapter addresses the first and second objectives of this thesis, the latter of which was to explore how the work of risk assessment and communication during the preoperative anaesthetic assessment is achieved.

After working through the objective and subjective aspects of the ISD to develop the BI prototype and explore the nature of the work it was intended to support, Chapter 6: Mortality after Surgery at Auckland City Hospital seeks to understand the substance of the data through quantitative methods. Consistent with the procedures for a single-centre, retrospective cohort study using RCD, 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital during 2002–2012 are described. This chapter addresses the third objective of the research and permitted an assessment as to the value of this information for use in preoperative risk assessment and communication.

In Chapter 7: Conclusion, the reader is encouraged to reflect on the research problem and objectives. The contributions of the research to theory, practice and education are identified; the limitations of the study are described; and implications and suggestions for future research are discussed.

1.8 Conclusion

In this chapter, I have given context to the research problem that is the subject of this thesis. I have briefly presented a summary of the background literature related to preoperative care, risk assessment and communication, and BI. This was followed by a summary of the research problem and the outlining of PAR as the method of enquiry used to disentangle it. The research context was described, including how the research problem came to be. I then summarised the content of the successive chapters as a guide to the flow of data collection and analysis, which culminated in a dual contribution to practice and scientific knowledge.
Chapter 2: Literature review

In the previous chapter, the research problem was introduced and the structure of the thesis outlined. In this chapter, the background literature is reviewed. A literature review surveys scholarly works and other sources relevant to a particular area of research and, in doing so, provides both summary and synthesis of these works in relation to the research problem being investigated [84]. It creates a “firm foundation for advancing knowledge, facilitates development of theory, closes areas where a plethora of research exists, and uncovers areas where research is needed” [85, p.xiii]. It follows that the purpose of this literature review is to synthesise and summarise works on the subjects of (1) preoperative anaesthesia assessment, (2) preoperative risk assessment, (3) the notion of EBM, research evidence and, more generally, sources of available information about perioperative risk, and (4) the learning healthcare system using RCD and BI (Figure 7). The literature review begins with the concept of the preoperative anaesthetic assessment of the surgical patient. The scope of this review is restricted to routine preoperative anaesthetic assessment of the adult patient undergoing elective, non-cardiac surgery.

![Figure 7. The structure of the literature review.](image)

2.1 Preoperative anaesthetic assessment of the surgical patient

Preoperative anaesthetic assessment is “the process of clinical assessment . . . which precedes the delivery of anaesthesia care for surgery and non-surgical procedures” [24 p. 522]. The
process is considered to be a basic element of anaesthesia care and includes an interview and examination of the patient; a review of the patient’s medical, surgical and anaesthesia history; an account of current medication use; and provisions for obtaining and reviewing diagnostic tests [24] (Figure 8). The assessment has three goals: (1) to evaluate medical conditions or factors that may increase the risk of complications, (2) to optimise these conditions or factors before surgery with the aim of reducing this risk, and (3) to estimate and communicate total (overall) risk to the patient [23-26]. However, the surgical patient population has changed drastically in recent years and preoperative assessment has evolved with it [29, 47]. Growing numbers of older and sicker patients coming forward for surgery [86, 87] mean that anaesthetists are increasingly involved in the decisions about the treatment options, including the option of foregoing surgery, for patients where medical risk is deemed to be high [26, 28]. On this basis, it could be argued that a fourth goal exists: to assist patients to make the choices about surgery and anaesthesia that best meet their needs. A preoperative consultation with an anaesthetist facilitates these goals [23] and is the focus of the subsections that follow.

![Preoperative anaesthetic assessment](image)

*Figure 8.* The three cornerstones of the preoperative anaesthetic assessment.

### 2.1.1 Patient interview

The patient interview is one of the three cornerstones of the preoperative assessment (Figure 8) [88] and is generally the anaesthetist’s first introduction to the patient [23]. The main objective of the interview is to elicit the patient’s medical history. A careful history is required to detect unrecognised disease that could increase the risks of surgery and anaesthesia [89] and to institute treatment to optimise the patient’s pre-existing medical conditions, thereby facilitating the delivery of appropriate and safe anaesthesia care [90] and reducing the likelihood of surgical complications [42]. Thorough preoperative assessment of the elderly is especially important because pre-existing disease, the use of multiple
medications, functional and mobility problems, and socioeconomic issues can all affect perioperative decisions and complicate recovery [91, 92]. As the same time, a thorough history has also been shown to be beneficial for seemingly healthy patients [93].

The interview should consider the patient’s specific medical, surgical, family and anaesthesia history [94]. Often this includes the indication for surgery; allergies to medications and substances such as latex; side-effects of medications; current and past medical problems; surgical history; major trauma; and current medications, including herbal and other nutritional or over-the-counter supplements [23, 88, 90]. A focused review of issues related to the planned anaesthetic procedures, including heart and lung function; possibility of pregnancy; personal or family history of anaesthetic problems; use of tobacco, alcohol and illicit substances; and functional capacity has also been shown to be pertinent [23, 89]. Lastly, it is important to establish the severity of pre-existing medical conditions by enquiring about current or recent exacerbations, the extent and activity-limiting nature of the problems, and previous treatment of the condition [90].

2.1.2 Physical examination

The physical examination builds on the information collected during the interview [27]. The examination usually includes measurement of main vital signs such as blood pressure, heart rate, respiratory rate, temperature, oxygen saturation, and weight and height [23, 90]. Examination of the head and neck is also performed. This allows the anaesthetist to anticipate potential difficulties during intubation [90]. A more extensive or focused examination is required for patients with specific medical conditions that may increase the risk of complications after surgery. These conditions may include heart or lung disease, kidney or liver problems and blood or nervous system disorders [88, 90]. The patient’s general appearance also provides invaluable information about their overall state of health. For example, breathlessness during conversation or with minimal activity, pallor, poor nutritional status, obesity and tremor may indicate underlying, and potentially undiagnosed, disease [89].

2.1.3 Preoperative tests

Blood tests and other diagnostic tests may be ordered following the interview and physical examination. The results of these tests are assumed to indicate increased likelihood of complications which may lead the anaesthetist to implement preventative measures or even recommend postponing or declining the patient’s surgery if potential harm outweighs the benefit of surgery [95]. Preoperative tests may be indicated for various purposes. According to the latest report by the American Society of Anaesthesiologists (ASA) Task Force on Preanesthesia Evaluation, these include, but are not limited to:
1) the discovery or identification of a disease or disorder that may affect perioperative anaesthetic care; 2) verification or assessment of an already known disease, disorder, medical or alternative therapy that may affect perioperative anaesthetic care; and 3) formulation of specific plans and alternatives for perioperative anaesthetic care. [24 p. 523]

Johansson [95] has suggested that several preoperative tests such as an electrocardiogram (ECG) or red blood cell count are considered by some anaesthetists to be a valuable baseline assessment to enable the detection of subsequent changes after surgery. However, routine preoperative blood tests or function tests such as chest X-ray are not recommended when the history and physical examination are not suggestive of abnormality [24, 96-101].

2.1.4 Documentation of the preoperative assessment

Anaesthetists typically document their findings from the patient interview, history and preoperative tests on a preoperative assessment form. This form is considered to be the mainstay of preoperative documentation for the anaesthetist because it contains the most extensive set of anaesthetic-related data [102]. Standardised, paper-based preoperative assessment forms are available in most institutions to assist the patient and anaesthetist to realise a comprehensive conception of the patient’s conditions [103]. Most of the information is pre-specified, but space is provided for free-hand notes [102]. Electronic-based preoperative assessment forms have also been developed [104, 105] with the aim of facilitating the exchange of information between health workers. The preoperative assessment form used at Auckland DHB is shown in Figure 9.

The preoperative assessment form has been likened to an information repository with three main purposes. In an ethnographic study of document use by anaesthetists, Harper [102] suggests that the first purpose is to enable the anaesthetist to formulate an anaesthetic plan. The second is to enable the anaesthetist to write notes that serve as reminders during the surgery. The third purpose is to enable the anaesthetist to “hand over” to a colleague. The last purpose is important because the anaesthetist performing the preoperative assessment frequently is not the procedural anaesthetist responsible for intraoperative management on the day of surgery [106].
Figure 9. The preoperative anaesthetic assessment template used at Auckland DHB. Permission granted for use by Dr Vanessa Bevis, Director of Anaesthesia and Operating Rooms, Auckland City Hospital.
2.2 Preoperative risk assessment

The three components of the preoperative assessment – interview, physical examination and preoperative testing – each represent an important input to risk assessment and risk
communication. The preoperative assessment facilitates early identification and assessment of factors which may predispose a patient to complications during surgery. The remainder of the preoperative assessment is concerned with modifying these factors to manage and ultimately reduce the likelihood of complications [88], or, in some cases, alternative treatment options, including foregoing surgery, because potential harm outweighs the benefit [95]. What remains after identifying risk factors and instituting treatment to mitigate the effects of these factors – the irreducible element of chance – is addressed with discussion about the total risks and benefits of different treatment or care options [43, 44] (Figure 10). Estimation of total risk is important because some patients might choose to forego planned surgery or consider less-invasive options when informed that their risk of adverse outcome is very high [33]. The focus of this section is on the subject of risk assessment during the preoperative assessment, beginning with an introduction to the concept of risk.

Figure 10. Risk assessment and communication during the preoperative anaesthetic assessment.

2.2.1 What is risk?

Many definitions of risk exist in common usage. Dictionaries define risk variably as a situation involving exposure to danger, or the probability or chance that something unpleasant or unwelcome will occur. The Oxford English Dictionary [14] cites the earliest use of the word in English (in the spelling of “risqué” from its French original “risque”) in the mid-17th century. The term may have initially entered Greek from Arabic (“rizq”), or entered French
through Italian (“risco” meaning “danger” and “rischiare” meaning “run into danger”) – either via ancient Greek or Latin [107]. An authoritative work on the subject of risk is a report entitled *Risk Assessment* that was published by Britain’s Royal Society in 1983. The report exemplified the prevailing international orthodoxy on the subject of risk [108] and continues to be a major work of reference today. In its report, the Society defined risk as:

*The probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge.* [109, p.22]

A similar conception of risk can be seen in Callon (developer of actor network theory) and colleagues’ [110] essay on technical democracy almost two decades later. The authors argued that political institutions must be expanded to include “hybrid forms” where experts and lay persons come together to explore sociotechnical controversies such as nuclear waste disposal. In their discussion on uncertainty and unforeseen concerns that result from rapid scientific and technological advances, the authors seek to delineate the terms risk and uncertainty. They also defined risk as a well-identified hazard, whose probability of occurrence can be determined within certain limits and under certain conditions. The identification of specific (adverse) events and their probability of occurrence can be considered common features of the notion of risk.

These threads are also common to the literature on perioperative risk. In a review of the preparation of adult patients for anaesthesia and surgery, Arvidsson [88] conceived of risk as the product of two distinct factors: probability and consequence. Consequence may be defined in this context as any kind of unwanted event following surgery and anaesthesia, and is more commonly referred to as a complication, or adverse outcome or event. It follows that risk (as it relates to surgery and anaesthesia and indeed to this thesis) may be defined as follows:

*The probability that a particular adverse event occurs during the perioperative period or results from undergoing anaesthesia and surgery.*

**2.3 A framework for risk assessment**

If risk is the probability that an adverse event will occur, risk assessment is the determination of quantitative or qualitative estimates of that probability. The risk of death and disability associated with surgery and anaesthesia is known to depend on a number of factors which may be determined pre- and intraoperatively [111]. Predictors of perioperative mortality generally fall into three broad categories: (1) those related to comorbid conditions of the patient, (2) those attributable to the nature of the surgery, and (3) those associated with
The risk of complications that are attributable solely to anaesthetic management is considered to be low [32, 54, 114]. This observation has led several authors to suggest that perioperative risk be interpreted at the intersection of two overarching risk factors: the general health of the patient and the nature of the planned surgery [34-37]. This framework (Figure 11) is expounded in the following subsections to review key patient- and surgery-specific risk factors for perioperative morbidity and mortality. The framework is used to structure thinking about perioperative risk throughout the subsequent sections of this thesis.

![Figure 11. Framework of ideas for interpreting perioperative risk.](image)

### 2.4 Patient risk factors

Assessment of general physical status is considered integral to the preoperative anaesthetic assessment [115]. Although there have been substantial advances in surgery and anaesthesia, elderly patients with comorbid disease continue to be at relatively increased risk of perioperative morbidity and mortality [116]. Advanced age and comorbidity as risk factors for perioperative mortality and morbidity are reviewed in the subsections that follow.

#### 2.4.1 Advanced age

Advanced age is a known predictive risk factor for mortality and morbidity after surgery [87, 117]. In comparison with younger patients, patients aged over 65 years undergoing elective surgery are at disproportionately higher risk of adverse postoperative outcomes, resulting from combinations of age-related physiological decline, higher likelihood of chronic medical illness or multiple comorbidity, polypharmacy, cognitive dysfunction, poor nutrition and geriatric syndromes such as frailty [86]. Age-related decline in reserve and function of
multiple organ systems is known to limit the physiological response to stressors, including acute illness, anaesthesia and surgery [118], leading to increased risk of complications.

Epidemiological studies of postoperative outcomes in elderly surgical patients have shown that the incidence of perioperative mortality increases progressively with age [119-122]. The incidence of overall mortality in the general population has been reported in the vicinity of ~1.0% compared with 30-day postoperative mortality of 2.2% for patients 60 to 69 years old [111], 2.9% for patients 70 to 79 years old [111], 5.8–6.2% in those patients aged 80 years or older [123] and 8.4% in patients 90 years of age and older [124]. Statistically significant differences in the rates of mortality for older patients when compared with younger patients have been reported for both major elective and emergency surgery after controlling for preoperative clinical and functional characteristics as well as the type of surgical procedure [111]. Increasing age is also considered an important determinant of death attributable to anaesthesia [125, 126].

Studies have shown that elderly patients also have a higher risk of perioperative morbidity compared with patients aged less than 65 years old. Polanczyk and colleagues [127], for example, evaluated the influence of age on perioperative complications and length of stay in patients undergoing non-cardiac surgery. Major complications occurred in 4.3% of patients aged 59 years or younger, 5.7% of patients 60 to 69 years of age, 9.6% of patients 70–79 years of age, and 12.5% of patients 80 years of age or older. Compared with patients aged 50–59, elderly patients aged 70 years of age or older who underwent major elective surgery were at increased risk for perioperative complications and death after adjustment for known risk factors, including functional status and type of surgery. In addition, age independently predicted longer hospital length of stay after adjustment for sex; ethnicity; preoperative clinical characteristics, including ASA score (see section 2.6.1); and type of procedure. More recently, Story and colleagues [87] conducted a prospective, observational study of elderly patients undergoing inpatient non-cardiac surgery in hospitals throughout Australia and NZ. Within the first five postoperative days, 20% of patients had experienced at least one complication. Those with a complication had a longer hospital length of stay and 14% of patients who suffered at least one complication died within 30 days after surgery. These findings are consistent with the results from the small number of North American and European studies that are available [120, 128-131].

2.4.2 Comorbid disease
Comorbid disease can predispose surgical patients to adverse outcomes. Although many definitions of comorbidity exist in common usage, the term is commonly used to describe the
“presence of additional diseases in relation to an index disease in one individual” [132 p. 359]. Findings from several inpatient studies have shown that diverse medical conditions, including history of ventricular arrhythmia, angina, hypertension, previous myocardial infarction, severe lung disease, asthma, obesity, diabetes, dementia, kidney disease and poor nutritional status, are predictors of adverse events following surgery [133-137]. Chung, Mezei and Tong [138], for example, studied the association between pre-existing medical conditions and adverse perioperative outcomes in 17,877 consecutive surgical patients in Toronto. After adjusting for age, sex, duration and type of surgery, several associations between pre-existing medical conditions and adverse outcomes were found to be statistically significant. Hypertension predicted the occurrence of intraoperative cardiovascular events, obesity predicted intraoperative and postoperative respiratory events and gastro-oesophageal reflux predicted intubation-related events [138]. After adjustment for demographic and clinical variables, studies of general surgical patients [139-143], orthopaedic patients [144-146] have also highlighted the association between increased perioperative mortality and morbidity, and the presence and severity of comorbid disease.

2.5 Surgical risk factors

Consideration of patient risk factors alone is insufficient for preoperative risk assessment. The ability to assess perioperative risk is limited without an appreciation of the magnitude and urgency of the proposed surgery.

2.5.1 Magnitude of the surgical procedure

Perioperative risk is related to the complexity and immediacy of surgery. The risk associated with the surgery itself may vary tremendously, depending on estimated blood loss, estimated fluid shifts, the duration of surgery and the anatomical site [147-150]. Large-scale studies have demonstrated low morbidity and mortality rates for a number of low-risk, superficial procedures that are performed in the outpatient setting [151]. Other large studies have reported that perioperative risk is higher among patients who undergo complex thoracic, abdominal or vascular surgery [152-155]. The need to assess surgical risk, as well as patient risk, is demonstrated in recent guidelines published by the ASA Task Force on Preanaesthesia Evaluation. The guidelines recommend evaluation by an anaesthetist prior to the day of surgery for patients with pre-existing disease and relatively healthy patients undergoing highly invasive, high-risk surgical procedures [24]. Therefore, to assess the overall perioperative risk, it is essential to consider factors relating to the proposed surgical procedure [34].
Few methods to gauge the magnitude of the surgery exist. Studies have previously used the British United Provident Association (BUPA) schedule in which procedures are rated by complexity on an eight-point scale from minor to complex major [36, 156]. Discrepancies are apparent because the schedule was intended to guide reimbursement of fees in private practice [157]. Alternatively, Pasternak and colleagues [158] at Johns Hopkins proposed a five-level classification based on location and extent of surgery, anticipated blood loss and fluid shift, and the need for monitoring in the ICU. Studies of major surgery commonly adopt this definition to refer to major surgery as procedures expected to last more than 2 hours [159].

The 2009 Focused Update on the American College of Cardiology/American Heart Association (ACC/AHA) 2007 guidelines on perioperative cardiovascular evaluation for patients undergoing non-cardiac surgery stratified surgical risk according to the invasiveness of the procedure. By definition, the reported rate of cardiac death and non-fatal heart attack is more than 5% in high-risk procedures (e.g. aortic surgery), between 1% and 5% in intermediate-risk procedures (e.g. prostate surgery), and less than 1% in low-risk procedures (e.g. cataract surgery) [89]. Not only are there few methods to gauge the magnitude of surgery, but those that exist, including the three-tiered ACC/AHA and five-tiered Pasternak rankings, are not interchangeable.

2.5.2 Urgency of the surgical procedure
Perioperative risk is also associated with the urgency of surgery. One of the most commonly used descriptors for urgency is the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) Classification of Intervention which came into effect in December 2004 [160]. Procedures are classified on a scale of 1 to 4, where 1 encodes an immediate life-, limb- or organ-saving intervention and 4 constitutes an elective surgical procedure that is planned or booked in advance of routine admission to hospital. The NCEPOD classification of interventions is depicted in Table 1, alongside example scenarios and typical procedures for each of the four categories. Using the NCEPOD classification, repair of a ruptured aortic aneurysm is classed as a category 1 immediate intervention, with the goal of getting the patient to the operating room within minutes of the decision to operate. A joint replacement, on the other hand, is scheduled in advance of routine hospital admission and is not considered a life-, limb- or organ-saving intervention, leading it to be classed as a category 4 elective intervention. Similar definitions of “urgency” are in use elsewhere and “emergency surgery” commonly refers to immediate or urgent interventions.
### Table 1. NCEPOD classification of interventions [161].

<table>
<thead>
<tr>
<th>Code</th>
<th>Category</th>
<th>Description</th>
<th>Target time to operating room</th>
<th>Example scenarios</th>
<th>Typical procedures</th>
</tr>
</thead>
</table>
| 1    | Immediate| Immediate (a) life-saving or (B) limb or organ-saving intervention. Resuscitation simultaneous with surgical treatment | Within minutes of decision to operate | • Ruptured aortic aneurysm  
• Compartment syndrome | • Repair of ruptured aortic aneurysm  
• Fasciotomy |
| 2    | Urgent   | Acute onset or deterioration of conditions that threaten life, limb or organ survival | Within hours of decision to operate and normally once resuscitation completed | • Compound fracture | • Debridement plus fixation of fracture |
| 3    | Expedited| Stable patient requiring early intervention for a condition that is not an immediate threat to life, limb or organ survival | Within days of decision to operate | • Stable and non-septic patients for wide range of surgical procedures | • Excision of tumour with potential to bleed or obstruct |
| 4    | Elective | Surgical procedure planned or booked in advance of routine hospital admission | Planned | • Encompasses all conditions not classified as immediate, urgent or expedited | • Joint replacement  
• Varicose vein surgery |

Emergency surgery is associated with increased risk of perioperative morbidity and mortality [139, 140, 162, 163]. Mangano determined that cardiac complications are 2 to 5 times more likely to occur after emergency surgery compared with elective surgery [152]. Higher postoperative mortality rates have been reported for specific subgroups of patients, including those undergoing elective and emergency surgery for repair of abdominal aortic aneurysm (6% vs 37%) [164], colorectal cancer (9% vs 19%, p<0.001) [165], ulcerative colitis (0.6% vs 13.1%, p<0.001) [166], coronary artery bypass (2.6% vs 4.7%, p<0.0001) [167] and liver resection surgery (8.8% vs 30.6%, p<0.001) [168]. Primatesta and Goldacre [169] also showed significant elevation of mortality after emergency inguinal hernia repair. Although hernia repair generally carries a low risk of major adverse sequelae, age- and sex-standardised mortality ratios per 1,000 operations within 12 months were 33.8 for emergency surgeries compared with 14.4 for elective surgeries. Mortality rates following elective repair showed no postoperative clustering, but death rates in the first months after emergency surgery were significantly higher than those in subsequent months. The authors concluded that at least half of the early deaths were likely attributable to the hernia itself, to the surgery on it, or to the sequelae of the surgery.
2.6 Risk scoring systems

Risk scores that combine patient and surgical risk factors have emerged to provide a more complete picture of the risks associated with surgery and anaesthesia. Increasing use of statistical methods based on multivariate analysis has made it possible to examine the contribution of many perioperative variables and their interaction in relation to important outcomes after surgery and anaesthesia [89, 111]. Using these methods, risk scores have been developed to predict outcome for individual patients [170-172]. These scores can be used to guide perioperative management and facilitate informed and shared patient decision-making [33, 170, 173].

Barnett [170] proposed that risk scores be classified according to whether they estimate individual or population risk, require pre-, intra- or postoperative data and estimate specific or non-specific types of complications. Five commonly used scoring systems designed to estimate perioperative risk for non-cardiac surgery are grouped below using this classification system (Table 2). Scores that estimate individual risk are further classified according to whether they predict specific complications or “generic” morbidity and mortality [170]. The Lee Revised Cardiac Risk Index (RCRI) [174], for example, was developed to estimate a patient’s risk of developing cardiac complications after surgery, whereas the APACHE II score was designed to predict postoperative mortality for patients admitted to the ICU. Risk scoring systems that estimate perioperative risk for individual patients may include only preoperative risk factors. The Charlson Comorbidity Index (CCI) [175] is an example of such a risk score. Alternatively, these scores may include a number of preoperative, intraoperative, and postoperative variables; for example, the Physiological and Operative Severity Score for the enUmeration of Morbidity and Mortality (POSSUM) [176].

Table 2. Classification of risk scores according to Barnett [170].

<table>
<thead>
<tr>
<th>Risk index</th>
<th>Cohort</th>
<th>Time period</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA-PS</td>
<td>Population</td>
<td>Preoperative only</td>
<td>Non-specific</td>
</tr>
<tr>
<td>CCI</td>
<td>Individual</td>
<td>Preoperative only</td>
<td>Non-specific</td>
</tr>
<tr>
<td>APACHE II</td>
<td>Individual</td>
<td>Postoperative only</td>
<td>Non-specific</td>
</tr>
<tr>
<td>POSSUM</td>
<td>Individual</td>
<td>Pre-, intra-, postoperative</td>
<td>Non-specific</td>
</tr>
<tr>
<td>RCRI</td>
<td>Individual</td>
<td>Preoperative only</td>
<td>Specific for cardiac complications</td>
</tr>
</tbody>
</table>

In addition to scores that estimate risk for individual patients, risk scores have been developed to describe population risk. The ASA Physical Status (ASA-PS) classification system [177-179], for example, is widely used to assess the physical status of patients before surgery and to estimate population risk. The classification allows groups of patients to be stratified
according to patient characteristics, permitting meaningful analysis of morbidity and mortality rates for the group [180].

Individual- and population-based risk scores are reviewed in the following subsections of this chapter. Several different scoring systems designed to estimate perioperative risk for non-cardiac surgery are detailed. The advantages and disadvantages for each of the systems are highlighted and examples from the literature are used to illustrate their utility. Although the APACHE II scoring system is intended for use in the ICU setting, attempts to use APACHE II to predict outcomes for patients outside this setting have yielded results which suggest use of the score could be extended to predict postoperative outcome [181-183] and therefore the score is included for completeness. A summary of this subsection is presented in Table 9.

2.6.1 ASA-PS

Anaesthetists worldwide routinely stratify patients according to severity of pre-existing disease and overall health using the ASA-PS (Table 3) [115]. ASA-PS is the simplest and most well-recognised classification of risk for patients undergoing surgery [184]. The classification was originally published in 1941 [178] and was subsequently modified in 1963 [179]. In its current form, patients are assigned a score on a 6-point ordinal scale prior to surgery, where class I indicates a fit and healthy patient and class V is reserved for a moribund patient who is not expected to survive without surgery. Class VI is used to designate organ retrieval in brain-dead patients and addition of the postscript “E” is used to indicate emergency surgery [37, 180].

Table 3. ASA-PS classification [177].

<table>
<thead>
<tr>
<th>ASA score</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A normal healthy patient</td>
</tr>
<tr>
<td>II</td>
<td>A patient with mild systemic disease&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>III</td>
<td>A patient with severe systemic disease&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>IV</td>
<td>A patient with severe systemic disease that is a constant threat to life</td>
</tr>
<tr>
<td>V</td>
<td>A moribund patient who is not expected to survive without the operation&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>VI</td>
<td>A declared brain-dead patient whose organs are being removed for donor purposes</td>
</tr>
</tbody>
</table>

<sup>a</sup> Qualified with “no functional limitation” in 1963 version.
<sup>b</sup> Qualified with “definite functional limitation” in 1963 version.
<sup>c</sup> Alternate criterion “Moribund patient unlikely to survive 24 h with or without operation” in 1963 version.

ASA-PS is simple in comparison to many existing risk scores and this confers several advantages. Anaesthetists determine the score based on information obtained from the preoperative interview and physical examination without the need for additional blood tests or diagnostic information [185, 186]. Many existing scores require preoperative data which may not be routinely collected for all patients, and diagnostic information that may not be available
until surgery is performed [171]. Unlike these scores, an ASA score can be assigned to every patient before surgery regardless of age, medical condition or degree of health [185]. The score is easy to commit to memory and many anaesthetists use it to describe their patients’ physical status to their colleagues [187]. The ASA-PS classification remains one of the truly prospective and widely applied descriptions of the patient, following age and sex.

Since underlying fitness is a strong predictor of survival after surgery, there is some of correlation between ASA score and postoperative outcome [188]. Probability models that describe the risk of mortality or morbidity related to surgery and anaesthesia have shown that ASA-PS is a major determinant of postoperative outcomes [136, 173]. The score has been used previously to stratify patients into categories of relative risk in which preoperative ASA score predicted increased length of stay, postoperative morbidity and mortality [35, 111, 123, 189-191]. For example, Vancanti et al. [189] demonstrated the relationship between increasing mortality and increasing ASA score in 68,388 cases. Wolters and colleagues’ [37] work in this area is also widely cited. The authors prospectively studied the association between ASA score, other perioperative variables and postoperative outcome in more than 6,000 patients. Univariate analysis showed significant association between ASA score and perioperative morbidity and mortality. In multivariate analysis, the strongest predictors of complications after surgery were ASA class IV followed by ASA class III, operative severity, ASA class II and emergency operation. The authors found a significant 5–7-fold stepwise increase in hospital mortality with each increase in ASA class.

At the same time, the limitations of the ASA score as a risk assessment tool are well documented in the literature. The ranking is a subjective measure conferred by the anaesthetist rather than an objective measure determined by the presence of specific disease states. Several studies have reported variability of ASA scores attributed to the same patient by different anaesthetists [115, 192-194]. In a study to assess consistency of use, Owens et al. [194] asked 255 anaesthetists to classify 10 hypothetical patients using ASA-PS. In six of the cases, there was general agreement among the anaesthetists with regard to the classification, suggesting that, although useful, the score is imprecise. ASA-PS does not account for age, smoking history, obesity or pregnancy; nor does it make any adjustment for the nature and magnitude of the proposed surgery [188]. Although it does allow for stratification of patients according to the severity of pre-existing disease [180], it does not distinguish among diseases of different organ systems or the nature of different diseases within the same organ system; nor does it cumulate risk based upon multiple conditions [185]. This means that a given score
could not differentiate perioperative management for a patient with asthma versus kidney disease.

ASA-PS provides valuable information about population risk, but is not able to predict outcome with confidence for individual patients in the absence of other perioperative variables [184]. The classification was never intended to estimate perioperative risk [187, 194]. Rather, it was originally intended to standardise physical status classification for retrospective analysis of hospital records [178]. Not surprisingly, studies have showed that ASA-PS has poor sensitivity [195, 196]. In a follow-on study by Wolters and colleagues, ASA-PS correctly predicted an uncomplicated course for 96% of patients, but complications were correctly predicted for only 16% of patients. The positive predictive value was 57% and negative predictive value was 80%. Dupuis [197] also compared the ability of the ASA score to predict cardiac complications. The score produced high sensitivity, but a lack of specificity for prediction of cardiac complications. When ASA classes II and IV were used as the cut-off point for the diagnosis of high risk, specificity was 82% and specificity was 58%. Hence, four out of five patients who were at high risk for postoperative cardiac complications were correctly identified as such, but two out of five patients who were not high risk were falsely identified as being at risk. The authors attributed these findings to the lack of adjustment for the nature of the proposed surgery because considerable differences in outcome exist for the same class of patients when different types of surgery are compared.

For this reason, many authors have developed risk scores that include ASA-PS along with other prognostic variables to better predict perioperative outcomes for patients undergoing non-cardiac surgery [173]. The Surgical Risk Score (SRS) combines the NCEPOD classification for interventions with the BUPA operative severity categories and ASA-PS [36, 160]. A simple sum of the numerical categories is used to derive the score. The SRS was found to be significantly predictive of postoperative mortality in patients undergoing low-risk surgery [36] and in a cohort of high-risk surgical patients [160]. Additionally, predicted mortality among high-risk surgical patients equalled that of other commonly used clinical risk scores [160]. Using a similar approach, Donati and colleagues [136] developed a model incorporating ASA-PS, age, type of surgery (elective, urgent, emergency), and magnitude of surgery (minor, moderate, major). The authors concluded that the model had better predictive performance than ASA-PS alone, and similar performance to other commonly used clinical risk scores.
2.6.2 CCI

CCI was originally developed to quantify comorbidity in longitudinal studies of medical and surgical patients [175, 198]. It is a method of predicting mortality by weighting comorbidities [175, 199, 200], where each condition is assigned a score of 1, 2, 3 or 6 depending on the risk of dying associated with each one (Table 4). The individual scores are summed to provide a total score to predict long-term mortality. The score is typically constructed from medical record abstracts or administrative data [201] and has been used widely in health research to measure the burden of disease [198]. The index was later modified to account for the effect of advanced age. Charlson and colleagues evaluated the modified index, called the Charlson Age Comorbidity Index (CACI), in a cohort of 226 patients undergoing elective non-cardiac surgery [202]. The authors concluded that the estimated relative risk of death from an increase of one in the comorbidity score was equivalent to that from an additional decade of age.

Table 4. CCI variables [175].

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial infarction</td>
<td>1</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>1</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>1</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>1</td>
</tr>
<tr>
<td>Dementia</td>
<td>1</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>1</td>
</tr>
<tr>
<td>Connective tissue disease</td>
<td>1</td>
</tr>
<tr>
<td>Ulcer disease</td>
<td>1</td>
</tr>
<tr>
<td>Mild liver disease</td>
<td>1</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1</td>
</tr>
<tr>
<td>Hemiplegia</td>
<td>2</td>
</tr>
<tr>
<td>Moderate or severe renal disease</td>
<td>2</td>
</tr>
<tr>
<td>Diabetes with end organ damage</td>
<td>2</td>
</tr>
<tr>
<td>Any malignancy</td>
<td>2</td>
</tr>
<tr>
<td>Moderate or severe liver disease</td>
<td>3</td>
</tr>
<tr>
<td>Metastatic solid tumour</td>
<td>6</td>
</tr>
<tr>
<td>Acquired immune deficiency syndrome (AIDS)</td>
<td>6</td>
</tr>
</tbody>
</table>

The original CCI and modified CACI have since been validated for prediction of in-patient morbidity and mortality in many different cohorts of surgical patients. CACI was shown to accurately predict length of hospital stay and postoperative mortality among patients undergoing colorectal surgery [203] and postoperative mortality among patients undergoing cardiac surgery [204]. CCI and ASA-PS yielded equivalent predictive ability in patients undergoing head and neck surgery [205] and radical prostatectomy [206]. However, the ASA-
PS was found to have better predictive ability than CCI in patients undergoing liver resection [207].

Although diverse experience with CCI has generally confirmed its predictive validity, the score is not widely used in clinical practice [208]. Barnett and Moonesinghe [170] identified a number of disadvantages of CCI in their review of clinical risk scores to guide perioperative management. Their account included the absence of information about the proposed surgery, and the potential for error in assigning the weighted individual score due to subjectivity inherent in the assessment of comorbidity. Fleisher [89] also highlighted the potential for inaccuracy and suggested that active conditions should be weighted more than dormant conditions in an attempt to reduce subjectivity.

2.6.3 The Acute Physiology and Chronic Health Evaluation (APACHE) II

APACHE II is a severity of disease classification system designed to predict postoperative mortality for patients admitted to the ICU [209]. The index includes a combination of 12 physiologic parameters (Table 5) as well as age, and the presence or absence of severe chronic health problems [208]. Individual scores for age, chronic health and physiology are added together to derive the APACHE II score. The worst values in the first 24 hours of admission to the ICU are used to derive an overall score between 0 and 71 [210]. An increasing score is closely correlated with subsequent risk of hospital death. Although the scoring system is intended for use in the ICU setting, attempts to use APACHE II to predict outcomes for patients outside this setting have yielded results which suggest use of the score could be extended to predict postoperative outcome [181-183].

Table 5. APACHE II physiological variables [209]

<table>
<thead>
<tr>
<th>Physiology variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Temperature (rectal)</td>
</tr>
<tr>
<td>Mean arterial pressure</td>
</tr>
<tr>
<td>pH arterial</td>
</tr>
<tr>
<td>Heart rate</td>
</tr>
<tr>
<td>Respiratory rate</td>
</tr>
<tr>
<td>Serum sodium</td>
</tr>
<tr>
<td>Serum potassium</td>
</tr>
<tr>
<td>Creatinine</td>
</tr>
<tr>
<td>Hematocrit</td>
</tr>
<tr>
<td>White blood cell count</td>
</tr>
<tr>
<td>Glasgow Coma Scale</td>
</tr>
</tbody>
</table>
APACHE II scores have shown to be predictive of mortality and morbidity in both general [211, 212] and surgical [213, 214] intensive care patients. Among patients in these studies, those who survived had a score ranging between 9 and 15, whereas those who died had higher mean scores ranging between 19 and 25. The index was recently recalibrated in a large representative population of UK critical care patients to permit calculation of standardised mortality rates in that setting [215]. Studies have also shown that preoperative APACHE II scores have superior predictive ability than the ASA-PS in the determination of morbidity and mortality after general surgery [182].

Application of the APACHE II index is limited in preoperative risk assessment. The score is unsuitable for anaesthesia [37] because it requires a 24 hour sampling period of the 12 physiological measurements [37]. Several components of the score also require special equipment or techniques (e.g. measurement of arterial blood gas), which may not be available outside of the ICU. Additionally, the score has not been universally predictive [216, 217] and some studies have found that APACHE II has the best prognostic features when applied to emergency rather than elective surgical patients [218]. This further limits its applicability in routine clinical practice [219].

2.6.4 POSSUM

POSSUM was developed by Copeland and colleagues as a retrospective tool for surgical audit [176]. The score is widely used in the UK and has been applied to a number of diverse surgical groups including patients undergoing orthopaedic surgery [220, 221], vascular surgery [222], head and neck surgery [223] and colorectal surgery [224]. POSSUM includes 12 physiological and 6 operative variables for the prediction of 30-day morbidity and mortality rates (Table 6). These variables are categorised on an exponential scale, summed to produce the physiological and surgical component scores, and subsequently entered into two separate logistic regression equations to obtain the percentage risk of postoperative morbidity or mortality. An alternative method using the same variables but different regression equations to predict postoperative mortality was later suggested, resulting in a variant called P-POSSUM [225]. Since then many other variants have been developed to facilitate its applicability to different subsets of surgical patients [224, 226, 227].
Table 6. POSSUM physiology and operative score variables [176]

<table>
<thead>
<tr>
<th>Physiology variables</th>
<th>Operative variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Grade of operation</td>
</tr>
<tr>
<td>Cardiac signs</td>
<td>Number of procedures</td>
</tr>
<tr>
<td>Respiratory signs</td>
<td>Total blood loss</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>Peritoneal soiling</td>
</tr>
<tr>
<td>Pulse rate</td>
<td>Presence of malignancy</td>
</tr>
<tr>
<td>Glasgow Coma Score</td>
<td>Timing of operation</td>
</tr>
<tr>
<td>Serum urea</td>
<td></td>
</tr>
<tr>
<td>Serum sodium</td>
<td></td>
</tr>
<tr>
<td>Serum potassium</td>
<td></td>
</tr>
<tr>
<td>Haemoglobin level</td>
<td></td>
</tr>
<tr>
<td>White blood cell count</td>
<td></td>
</tr>
<tr>
<td>Electrocardiogram result</td>
<td></td>
</tr>
</tbody>
</table>

Several empirical studies have shown POSSUM scores accurately predict morbidity and mortality. The score has been validated in many studies and is able to accurately predict postoperative morbidity in major abdominal surgery as well as colorectal, liver and vascular surgery [228-232]. Pratt and colleagues [233] assessed whether use of the score might correlate with clinical and economic outcomes for patients undergoing pancreatic resection. The authors studied 326 consecutive pancreatic resections between October 2001 and January 2007 and found that clinical and economic outcomes worsened with increasing POSSUM scores. Observed (O) versus expected (E) mortality rates were similar (53.1% vs 55.5%), with an overall O/E ratio of 0.96 suggesting that POSSUM is a valuable perioperative scoring system that can be employed to guide perioperative management. Similarly, Neary and colleagues [148] compared the predictive ability of POSSUM and the Hardman Index, a risk score designed to improve selection of patients for repair of ruptured abdominal aortic aneurysm. Although both POSSUM and Hardman score were significantly associated with increased postoperative mortality (p< 0.001), the POSSUM score identified a higher number of patients at risk.

Use of POSSUM for preoperative risk assessment is limited. The score was originally devised as a retrospective tool for surgical audit and not a prospective risk index for perioperative outcomes. For this reason, several of the operative variables are recorded postoperatively and some of these variables, such as the presence of malignancy, may not be available for a considerable period of time [184]. Other components of the score include blood analysis, an ECG and a chest X-ray, which may not be clinically indicated or universally available. Inclusion of these variables limits the utility of POSSUM for preoperative risk assessment.
The score has also been criticized for overestimating mortality, especially among low-risk patients [225, 234]. Whiteley and colleagues found that POSSUM overpredicted risk of postoperative mortality by a factor of six in patients with an estimated risk of mortality of 10% or less [232]. Copeland’s equation for mortality returns a minimum predicted mortality of 1.08%, which likely exceeds that expected for a fit patient undergoing minor surgery [232, 235]. Overestimation of risk led to the development of alternative risk equations, including those devised for specific patient groups. These scores are derived from individual specialty datasets providing improved predictive accuracy, but at the expense of generalisability and cross-specialty comparisons [184].

### 2.6.5 RCRI

RCRI was developed by Lee and colleagues [174] and is a widely adopted approach to quantifying cardiac risk in relation to major elective non-cardiac surgery. The index was derived from 2,893 patients and validated in a cohort of 1,422 patients aged 50 years or over and scheduled to undergo major non-cardiac surgery. Lee et al. identified six independent variables that predicted a 2–3-fold increased risk for cardiac complications (Table 7). Each of the six risk factors is allocated one point and the sum of the points gives an estimate of perioperative cardiac risk. A patient’s risk for perioperative cardiac complications increases with the number of variables present (Table 8).

#### Table 7. Risk factors for RCRI [174]

<table>
<thead>
<tr>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-risk type of surgery</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
</tr>
<tr>
<td>History of congestive heart failure</td>
</tr>
<tr>
<td>History of cerebrovascular disease</td>
</tr>
<tr>
<td>Insulin therapy for diabetes</td>
</tr>
<tr>
<td>Preoperative serum creatinine $&gt;2.0$ mg/dL</td>
</tr>
</tbody>
</table>

#### Table 8. Risk of cardiac complications by RCRI class and number of risk factors [174]

<table>
<thead>
<tr>
<th>RCRI class</th>
<th>Number of risk factors</th>
<th>Risk of cardiac complications % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0</td>
<td>0.4 (0.05-1.5)</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>0.9 (0.3-2.1)</td>
</tr>
<tr>
<td>III</td>
<td>2</td>
<td>6.6 (3.9-10.3)</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>11 (5.8-18.4)</td>
</tr>
</tbody>
</table>

RCRI is widely adopted in clinical practice and research [89]. The performance of the score was evaluated in a recent systematic review of 24 studies reporting on a total of 792,840 patients [236]. RCRI discriminated reasonably well between patients at low as opposed to
high risk for adverse cardiac events following mixed non-cardiac surgery (area under the curve [AUC] 0.75 [95% confidence interval (CI), 0.72 to 0.79]); sensitivity, 0.65 [CI, 0.46 to 0.81]; specificity, 0.76 [CI, 0.58 to 0.88]; positive likelihood ratio, 2.78 [CI, 1.74 to 4.45]; negative likelihood ratio, 0.45 [CI, 0.31 to 0.67]). Prediction of adverse cardiac events following vascular surgery alone was less reliable (AUC, 0.64 [CI, 0.61 to 0.66]; sensitivity, 0.70 [CI, 0.53 to 0.82]; specificity, 0.55 [CI, 0.45 to 0.66]; positive likelihood ratio, 1.56 [CI, 1.42 to 1.73]; negative likelihood ratio, 0.55 [CI, 0.40 to 0.76]). A more recent study [237] not included in the review by Ford and colleagues reported an AUC of 0.73 for RCRI in vascular patients undergoing endovascular abdominal aortic aneurysm. Goldman [238] attributes the inconsistent performance of RCRI for vascular procedures to wide variations among the classification of vascular patients at different institutions, different definitions of risk factors or outcome events, or use of more sensitive biochemical assays for diagnosis. Despite this limitation, its predictive performance and ease of use resulted in RCRI being incorporated into the 2007 preoperative cardiac risk evaluation guidelines from the ACC/AHA [89]. However, studies do not support use of RCRI for predicting all-cause mortality after major non-cardiac surgery [236]. This finding is not surprising because RCRI was designed to predict only cardiac-related complications. For this reason, the score does not include predictors of other important perioperative complications, such as pulmonary complications or surgical-site infections [239, 240]. Cardiac causes account for approximately one-third of perioperative deaths [241] so other risk indices are required to predict generic morbidity and mortality.

Although this subsection has identified many scores and models for predicting morbidity and mortality after surgery (see Table 9), few of these tools achieve the twin goals described by Moonesinghe and colleagues [242] of being derived entirely from data that are available in the preoperative period and of being accurate, parsimonious and easy to use in the clinical setting. Many of these tools are not readily used in everyday practice and this is likely to be due, in part, to concerns regarding the number of tools and their complexity and accuracy [243]. Furthermore, there is a growing body of evidence to suggest that a high percentage of postoperative complications and deaths occur after 30 days postoperatively [244], so data beyond this period could be used to provide useful risk information to patients before surgery and anaesthesia [245]. Yet, many of these tools do not consider outcomes for patients beyond 30 days after surgery. Instead of relying exclusively on risk scores and models, anaesthetists tend to draw on multiple sources of information including RCTs and findings from other primary studies, clinical judgement and convenient heuristics to aid their assessment of
perioperative risk. The evidence base for this assessment is discussed in the sections that follow.

**Table 9. Summary of current methods for preoperative risk assessment.**

<table>
<thead>
<tr>
<th>Risk index</th>
<th>Description</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA-PS</td>
<td>Six-point ordinal scale that provides a subjective assessment of a patient’s overall health [178, 179]</td>
<td>Simple and easy to commit to memory [187]</td>
<td>Inter-observer variability [115, 192-194]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does not require additional blood tests or diagnostic information [185, 186]</td>
<td>Poor sensitivity and specificity for prediction of morbidity and mortality for individual patients [195, 196]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Included in many risk prediction scores alongside other prognostic variables [36, 136, 160]</td>
<td></td>
</tr>
<tr>
<td>CCI</td>
<td>Point scoring system for the presence specific comorbidities used to predict long-term mortality [175, 199, 200]</td>
<td>Widely used in health research [198]</td>
<td>Score does not include information about the proposed surgery [170]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Validated in a number of settings [203-206]</td>
<td>Subjective assessment of comorbidity [170]</td>
</tr>
<tr>
<td>APACHE II</td>
<td>Severity of disease classification system designed to predict postoperative mortality for patients admitted to the intensive care unit (ICU) [209]</td>
<td>Validated in a number of settings [211-214]</td>
<td>Requires 24-hour sampling of physiological variables and specialist monitoring not routinely available outside the ICU [37]</td>
</tr>
<tr>
<td>POSSUM</td>
<td>Detailed scoring system comprising of 6 operative variables and 12 physiological variables used to predict 30-day, all-cause mortality or morbidity [176]</td>
<td>Validated in a number of settings [228-232]</td>
<td>Some variables cannot be ascertained until after surgery [184].</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variations in the model have been devised for specific groups of patients with improved predictive performance [224, 226, 227]</td>
<td>Overestimates mortality among lower acuity patients [225, 234].</td>
</tr>
<tr>
<td>RCRI</td>
<td>A six-variable score that gives an estimate of perioperative cardiac risk for patients undergoing major, elective non-cardiac surgery [174]</td>
<td>Discriminates reasonably well between patients at low as opposed to high risk for cardiac events after mixed non-cardiac surgery [236]</td>
<td>Not recommended for predicting all-cause mortality after major non-cardiac surgery so other risk indices are required [236]</td>
</tr>
</tbody>
</table>

### 2.7 Evidence-based preoperative risk assessment

In NZ, the content of anaesthetists’ discussions about the benefits and risks of undergoing surgery is influenced by the Guidelines on Consent for Anaesthesia or Sedation issued by the Australian and New Zealand College of Anaesthetists [246]. According to the guidelines, “the discussion of risks and benefits should include those associated with the proposed treatment, alternative treatments, or no treatment at all” [246, p.2]. In considering risks to be discussed with the patient, anaesthetists are advised to use the “reasonable person” standard. The guidelines suggest that anaesthetists ask themselves (1) whether a reasonable person, in the position of the patient, would be likely to attach significance to the risk and (2) whether the
anaesthetist is aware or should be reasonably aware, that this particular patient would be likely to attach significance to that risk, such that they may choose to forgo having the procedure if informed of that risk [246]. On the subject of risk more specifically, the guidelines state that anaesthetists should explain known risks “when an adverse outcome is rare, but the detriment severe” [246 p.3], such as neurological damage or death and “an adverse outcome common but the detriment slight” [246 p.3], such as sore throat or nausea and vomiting. In addition, “the uncertainty of adverse outcomes/events should be explained, as should the difficulty of relating the incidence of such events to the [individual] patient” [246 p.3].

Ultimately, these guidelines mean that anaesthetists must decide which risks to disclose to patients, and what incidences to quote for those risks [54]. Their estimation of risk is based on knowledge about the incidence of adverse events in groups of patients that share the same patient- and surgery-specific risk factors as the individual patient being assessed [88]. In estimating the risk for an individual patient, the anaesthetist will consider the patient’s medical conditions, therapies, alternative treatments, surgical and other procedures, and options for anaesthetic techniques [24]. This information is melded with evidence extrapolated from clinical research and guidelines, personal experience with previous cases, pathophysiological knowledge, patient preferences for alternative forms of care, and convenient heuristics [49-53] to inform their discussions about the risks, benefits and expectations of undergoing surgery.

As the “gold standard” for evaluating the efficacy of therapeutic interventions, evidence from well-executed RCTs is considered the strongest foundation to inform perioperative patient care. Many of the design features specific to the RCT function to limit the influence of systemic differences between study groups and reduce spurious causality and bias. These features increase the internal validity of causal inferences made on the basis of findings from RCTs, often at the expense of their generalisability. This tension is discussed in the following subsections of this chapter. First, the notion of EBM is introduced. Second, the RCT is defined and the design features of the method are described. Third, the validity of inferences from RCTs (and clinical studies in general) is discussed with particular reference to the generalisability of findings. Fourth and finally, the limitations of the RCT as a method for the study of perioperative outcomes are reviewed.

2.7.1 EBM
Over the past few decades, there has been a growing interest in making healthcare decisions based on research findings [247]. EBM or, more generally, evidence-based healthcare,
evolved as a strong research literacy movement to accelerate this process [248]. The phrase was first coined by Sackett and colleagues in the *ACP Journal Club* in 1991 [249] and was later defined as the “conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients” [250 p. 71]. As this definition has evolved, EBM has spawned a plethora of related activities that extend beyond the immediate domain of clinical decision-making healthcare, such as evidence-based planning, policy-making [251] and management [252].

Broadly speaking, the goals of EBM are to improve patient care through the systematic application of medical knowledge. Since EBM came to the fore more than two decades ago, the landscape of healthcare has changed dramatically and important developments in EBM have been made. In its original formulation, EBM lay emphasis on the need for clinicians to move away from an experience-based form of clinical practice and promoted the examination of evidence from research. In their 1992 paper published in *JAMA*, the Evidence-Based Medicine Working Group heralded the introduction of EBM as a new paradigm for the practice of medicine. The authors delineated EBM as a practice that “de-emphasizes intuition, unsystematic clinical experience, and pathophysiologic rationale as sufficient grounds for clinical decision making and stresses the examination of evidence from clinical research” [253, p.2420].

A growing interest in the subject of knowledge transfer between research and practice in clinical settings has led some authors to emphasise the emancipatory quality of EBM. Clinicians are faced with a growing body of evidence, much of it invalid or irrelevant to their day-to-day practice [254]. This is amid concerns over the failure to consistently translate healthcare research evidence into clinical practice and policy [255]. Guyatt and others [256] have delineated a role for EBM in the management of clinicians’ information needs, thus empowering them to develop their own views on claims and controversies in medical practice [256-258]. Given the current emphasis on patient-centred care [259], Haynes and colleagues address a criticism often levelled at EBM – that it “robs patients of their personal choices in reaching a decision about optimal care” [260 p. 1350]. The authors suggest that the term was coined to encourage clinicians and patients “to pay due respect – no more, no less – to current best evidence in making decisions” [260 p. 1350].

Though the goals of EBM are broad, its approach is rather more prescriptive. EBM instils an awareness of the evidence upon which clinicians’ practice is based and relies on their being cognisant of the strength of inference permitted by that evidence [261]. The process of EBM is comprised of four main steps. These are described by Rosenberg and Donald [254 p. 1122]
and include: (1) formulate clear clinical questions from a patient’s problem, (2) a thorough search of the literature for articles that relate to the questions, (3) a critical appraisal of available evidence for its validity and its applicability to the clinical situation, and (4) a balanced application of the conclusions to the clinical problem.

In its earliest form, the model of EBM consisted of three components that may bear on the clinical management of a patient’s condition: (1) clinical expertise, (2) patient preferences for alternative forms of care, (3) and clinical research evidence [262]. More recently, the model was redefined to integrate (1) research evidence, (2) the patient’s clinical state and circumstances, (3) their values/preferences and actions, and (4) clinical experience (Figure 12) [260]. Drawing on this model, Haynes and colleagues illustrated the interplay between the components that might impact on the clinical management of the patient’s condition:

*Clinical decisions must include consideration of, firstly the patient’s clinical and physical circumstances to establish what is wrong and what treatment options are available. Secondly, the latter need to be tempered by research evidence concerning the efficacy, effectiveness, and efficiency of the options. Thirdly, given the likely consequences associated with each option, the clinician must consider the patient’s preferences and likely actions (in terms of what interventions he or she is ready and able to accept). Finally, clinical expertise is needed to bring these considerations together and recommend the treatment that the patient is agreeable to accepting.* [260 p. 1350]

![Figure 12. A model for evidence-based clinical decisions](Image)
Sackett and colleagues are explicit on the subject of primacy accorded to any of the four components. The authors have laboured the point that, for any given decision, clinical expertise or patient preferences may supersede the other components of the model. This point has been made since the inception of EBM and most notably in Sackett and colleagues’ paper published in the *British Medical Journal* titled “Evidence-based Medicine: What It Is and What It Isn’t”. For example, patient preference will take precedence in the event that a patient declines a blood transfusion on religious grounds, even if research evidence and clinical circumstances dictate that transfusion is the best course of action [260, 262, 263].

### 2.7.2 Research evidence in EBM

EBM recognises that research evidence, ranging from preliminary pathophysiological studies in humans to applied clinical research, is not created equal. The EBM model is intended as a guide to help clinicians to source the most rigorous and relevant evidence for a specific clinical decision [263]. Systematic reviews of RCTs are widely considered to be the most reliable form of scientific evidence for assessing the effectiveness of healthcare interventions. This belief is reflected in a number of “evidence hierarchies” that represent the relative strength of the evidence produced by study designs commonly used in medical research. The “hierarchy of evidence” is a framework to assist with the assessment of the evidential weight and relevance of research inputs into clinical decision-making [264] and, more generally, for ranking evidence that evaluates healthcare interventions [265]. One of the most common representations lists several study designs ranked in order of decreasing internal validity [264]. The hierarchy indicates which type of study design should be given the most weight in an evaluation where the same question has been examined using different study designs [266]. The emphasis on assessing the effectiveness of interventions has supported a hierarchy of evidence (Table 10) that places RCTs and derivatives at the top (step 1), uncontrolled studies and expert opinion based on physiology, bench research or first principles at the bottom (step 5), and controlled observational studies somewhere in between (steps 2–4) [267-269].
### Table 10. Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence [270]

<table>
<thead>
<tr>
<th>Question</th>
<th>Step 1 (Level 1)</th>
<th>Step 2 (Level 2)</th>
<th>Step 3 (Level 3)</th>
<th>Step 4 (Level 4)</th>
<th>Step 5 (Level 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What will happen if we do not add a therapy? (Prognosis)</td>
<td>Systematic review of inception cohort studies</td>
<td>Inception cohort studies</td>
<td>Cohort study or control arm of RCT</td>
<td>Case-series or case-control studies, or poor quality prognostic cohort study</td>
<td>N/A</td>
</tr>
<tr>
<td>Does this intervention help? (Treatment benefits)</td>
<td>Systematic review of RCT or n-of-1 trials</td>
<td>RCT or observational study with dramatic effect</td>
<td>Non-randomised controlled cohort/follow-up study</td>
<td>Case-series, case-control studies, or historically controlled studies</td>
<td>Mechanism-based reasoning</td>
</tr>
<tr>
<td>What are the COMMON harms? (Treatment harms)</td>
<td>Systematic review of RCT, systematic review of nested case-control studies, n-of-1 trial with the patient you are raising the question about, or observational study with dramatic effect</td>
<td>Individual RCT or (exceptionally) observational study with dramatic effect</td>
<td>Non-randomised controlled cohort/follow-up study (post-marketing surveillance) provided there are sufficient numbers to rule out a common harm. (For long-term harms the duration of follow-up must be sufficient.)</td>
<td>Case-series, case-control, or historically controlled studies</td>
<td>Mechanism-based reasoning</td>
</tr>
<tr>
<td>What are the RARE harms? (Treatment harms)</td>
<td>Systematic review of RCT or n-of-1 trial</td>
<td>RCT or (exceptionally) observational study with dramatic effect</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2.7.3 Why RCTs?

The RCT is a form of experimental research “founded on the assumption that the changes that occur in a given, confined part of nature can be explained in terms of cause-effect relations” [271 p. 47]. Through experimentation, researchers manipulate one or more independent variables and then observe, measure and record the outcome, which is often the dependent variable or leads to its determination [271]. In their work *Quasi-Experimentation: Design and Analysis Issues for Field Settings*, Cook and Campbell [272] defined an experiment as a test that involves a treatment (possible cause), an outcome measure (possible effects of the treatment), units of assignment, and some comparison from which change can be inferred and attributed to treatment. This definition was later modified to emphasise the deliberate application of the intervention. According to the revised definition, an experiment is “a study in which an intervention is deliberately introduced to observe its effects” [273 p. 12].

The literature on the purpose, methods and limitations of RCTs is vast. One of the most comprehensive, yet accessible accounts is provided by Jadad [274]. Jadad wrote that the RCT
is, in essence, a study in which people are randomly assigned to receive one of several clinical interventions (Figure 13). The study participants are collectively referred to as the “sample population”; they represent a subset of the population of interest. Study participants are allocated at random to either an experimental treatment group or to a control group through a process of randomisation. The former receive an intervention that may potentially affect their health such as a screening test, diagnostic test or interventional procedure. The latter receive a comparison or control (see Cook and Campbell [272 p. 7-8] for alternative uses of “control”) which may be a placebo, the current standard of care or no intervention at all. Regardless of the allocation, all study participants are followed up over a specified period of time in the same manner. At the end of the study, the investigators measure and compare different a priori specified outcomes that are present or absent after the study participants have received their allocated intervention. RCTs, when appropriately designed, conducted, and reported, provide the best estimate of the effects of an intervention on a defined group of participants [275].

Figure 13. The basic structure of a RCT. Adapted from McGovern et al. [276].

The unique capability of the RCT to reduce spurious causality and bias depends on random assignment to treatment and control groups [277]. Schulz and Grimes [277], in their paper on the generation of allocation sequences in RCTs in *The Lancet*, suggest that randomisation affords at least three major benefits. True randomisation eliminates bias in treatment assignment, ensures that the identity of the intervention is concealed from investigators, participants and assessors, and permits the use of probability theory to express the likelihood that any difference in outcome between treatment groups is due to chance and chance alone. Random allocation of participants to treatment or control groups is not intended to guarantee...
that the two groups will be equal in all known prognostic factors. Rather, randomisation ensures that such differences are due to chance so that demographic and prognostic characteristics among participants in different treatment groups are likely to be comparable at the start of the study [278, 279]. The process of randomisation ensures that systemic differences between study groups do not influence the study outcomes, thereby giving investigators the best chance of isolating and quantifying the impact of the intervention they are assessing [274]. Interested readers are directed to Sibbald [280], Roberts [278], Greenhalgh [268] and Jadad [274] for further discussion on the salient design features of the RCT.

2.7.4 Validity of research evidence

EBM and the hierarchy of evidence both highlight the goal implicit in all clinical research – to draw inferences about how treatment should be applied to a general population of future patients [281, 282] in light of what has been learned from the experience of others. In their writings that popularised the concept of the quasi-experiment, Shadish, Cook and Campbell, proffer the term validity to refer to the approximate truth of these inferences [273 p. 34]:

*When we say something is valid we make a judgement about the extent to which relevant evidence supports that inference as being true or correct. Usually, that evidence comes from both empirical findings and the consistency of these findings with other sources of knowledge, including past findings and theories.*

Two main types of validity – internal and external – are invoked when developing a framework to apply to experiments in complex field settings (Table 11). The seminal writings of Campbell and Stanley [283] on the typologies of research design validity popularised the distinction between internal and external validity, which Campbell [284] originally made in 1957. Internal validity was defined as “the basic minimum without which any experiment is uninterpretable: Did in fact the experimental treatments make a difference in the specific experimental instance?” [283 p. 5]. External validity, according to Campbell and Stanley, “asks the question of generalizability: To what populations, settings, treatment variables, and measurement variables can this effect be generalized?” [283 p. 5].

Cook and Campbell [272], following Campbell [284] and Campbell and Stanley [283], further subdivided the two validity types to yield a four-part classification of experimental validity. The four types of validity are statistical conclusion validity, internal validity, construct validity and external validity. For improved comprehension and ease of reference, the definitions of these constructs as they appear in *Quasi-Experimentation* are provided in Table
According to these authors, investigators make definite judgements about whether the presumed cause and effect covary and how strongly they covary (statistical conclusion validity), whether observed covariation as operationalised is causal (internal validity), how the operationalised treatment and outcome variables should be labelled (construct validity), and across what persons, places and times the relationship generalises (external validity).

Table 11. Four types of validity [285].

<table>
<thead>
<tr>
<th>Validity Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical conclusion validity</td>
<td>The validity of inferences about the correlation (covariation) between treatment and outcome</td>
</tr>
<tr>
<td>Internal validity</td>
<td>The validity of inferences about whether observed covariation between A (the presumed treatment) and B (the presumed outcome) reflects a causal relationship from A to B as those variables were manipulated or measured</td>
</tr>
<tr>
<td>Construct validity</td>
<td>The validity of inferences about the higher order constructs that represent sample particulars</td>
</tr>
<tr>
<td>External validity</td>
<td>The validity of inferences about whether the cause-effect relationship holds over variation in persons, settings, treatment variables, and measurement variables</td>
</tr>
</tbody>
</table>

The validity typology both helps to determine the nature of research design in practice, as suggested by Mark [286] in his paper on validity typologies and practice of quasi-experimentation, and recognises that research design choices require trade-offs. In his writings on the judgement calls in research, McGrath’s [287] discussion of the “three-horned dilemma” highlights these trade-offs. He argues that the research process is best viewed as a sequence of interlocking choices in which investigators try to uphold a number of mutually incompatible research goals. Viewed in this way, “the research process is to be regarded as a not as a set of problems to be ‘solved,’ but rather as a set of dilemmas to be lived with” [287 p. 69]. Central to McGrath’s writings is the notion that all research strategies and methods are flawed largely because the very strengths in relation to one desideratum will often function as potential weaknesses in relation to other, equally important research goals.

McGrath goes on to describe three conflicting desiderata. He suggests that all research evidence involves some population, exhibiting some behaviour, in some context. It is desirable to maximise (1) generalisability to the population affecting external validity; (2) precision in measurement and control of the behavioural variables, affecting internal and construct validity; and (3) realism of context. Yet, the very choices and operations that are sought to maximise any one of these desiderata will simultaneously reduce the other two. By the same logic, the choices that would optimise research outcomes for any two desiderata will minimise those for the third. Thus, “the research strategy domain is a three-horned dilemma, and every research strategy either avoids two horns by an uneasy compromise but gets
impaled to the hilt, on the third horn; or it grabs the dilemma boldly by one horn maximising on it, but at the same time ‘sitting down’ (with some pain) on the other two horns” [287 p. 74].

In the following sections, research design trade-offs are discussed as they relate to clinical research in anaesthesia and surgery. The following subsections will give minimum attention to statistical, internal and construct validity. Instead, primary attention will be afforded to the construct of external validity. The reason for this is because anaesthetists take into account relevant RCTs and systematic reviews in their assessment of perioperative risk and relevance depends on external validity; that is, “whether the results can be reasonably applied to a definable group of patients in a particular clinical setting in routine practice” [53, p.82].

2.7.5 Generalising from RCTs and clinical research studies

Systematic reviews of well-executed RCTs yield the most reliable information about clinical outcomes in anaesthesia and perioperative medicine. By virtue of their design, RCTs allow researchers to establish a causal link between treatments and observed outcomes [275, 280, 282, 288-291]. To establish this link requires the exclusion of other possible causes or differences through standardisation and control-specific eligibility criteria, random allocation to treatment groups, defined therapies, careful follow-up, appropriate statistical analyses, and adequate sample size [53, 282, 292, 293]. These measures increase the internal validity of inferences made from RCTs, often to the detriment of the applicability of its results.

As well as being internally valid, evidence from clinical research must also be relevant to clinical practice. External validity is the extent to which the results from a study can be reasonably applied to a well-defined group of patients in a specific clinical setting in everyday practice [53]. The concept has also been variously termed applicability [294] or generalisability [53]. In some instances, the effects attributed to a study intervention appear to generalise to the vast majority of patients and settings (e.g. the effects of the oral contraceptive pill), but the ability to generalise the effects of other interventions will often depend on factors such as the characteristics of the patient, the nature of the intervention and its method of application, and the setting of study [55]. RCTs are designed to assess the “average” treatment effect in the group of patients that is enrolled [295, 296]. Therefore, “even if the intervention provides a significant benefit in the patients studied, whether and for whom it should be used in routine practice remains a matter of judgement for the treating clinician” [55 p. 923]. Anaesthetists must decide whether the results of clinical studies can be generalised to the patients they see in their own practice when using reported incidences of outcomes to communicate the risks of anaesthesia and surgery [54, 282, 297]. In deciding
how best to adopt the results of a study, consideration must be given to clinician-, patient-, healthcare setting- and treatment-related differences between the study setting and real-world clinical practice [49, 53, 298-300]. These aspects are appraised in the following sections and summarised in Table 12.

The generalisability of clinical studies may be reduced by atypical treatment. RCTs employ a protocol or plan to guide patient care activities [301]. The protocol provides an explicit statement about what needs to be done for patients (and what data to collect), at what intervals, and by whom [302, p. 518-519]. Patient care activities are carried out in accordance with the protocol and deviations are carefully recorded. Patients who participate in a trial may require additional laboratory tests, imaging or consultations with other specialist doctors, which may not be part of routine practice [303]. Differences in the trial intervention itself may extend to the formulation and bioavailability of a drug, or the type of anaesthetic used for an operation [53]. Patient care in usual practice may vary substantially from that specified in the protocol [295, 304]. In routine practice, new or different technologies and techniques may be utilised, treatments may be combined, compliance with treatment regimens may be poor, and neither patient nor caregiver is blinded to any aspect of it [298, 305]. The use of study protocols may afford trial participants higher-quality care, no matter what arm of the study they are in [306, 307]. The experimental nature of clinical studies in which patient care is protocol-driven and methods of diagnosis or treatment may not be routine makes it difficult to know how well the results will apply to everyday practice.

Patients who participate in clinical trials may not be representative of the patient population for whom the intervention is intended. Strict selection criteria are applied to clinical trials to ensure the results are internally valid [299]. These criteria may remove patients with compromised kidney function [308], women [309, 310], the very young [311, 312] and very old [313-316], those on medications potentially interacting with the study medication/s, ethnic minority groups [317, 318], patients with multiple pre-existing medical conditions [319, 320] including psychological conditions, or those with a history of illicit drug or alcohol abuse [321]. Patients who are not eligible to participate in a trial because of sex, biological factors, or ethnic and cultural factors may have different outcomes from those who are eligible and do participate in a trial [53, 322]. Many of the patients excluded from trials are those most likely to require treatment. Selection criteria may limit the availability of empirical data on complicated and severely ill patients whom doctors cannot exclude from everyday practice [295]. Claessens et al. [323], for example, found that selection criteria for high-quality trials
on severe infection excluded most of the patients they encountered in everyday practice, leading to impaired generalisability of results.

Patients who meet the trial eligibility criteria may not necessarily be recruited to the study. Most studies do not report their recruitment rates, but those that do suggest rates are typically low [53, 300, 324]. Many eligible persons are not enrolled because they are “difficult to recruit” [325 , p. 336]. This includes members of ethnic minority groups, for whom language, cultural factors, beliefs about medical research and the appropriateness of the trial protocol may be significant barriers to recruitment [325]. Doctors may decline to enrol eligible patients based on their own treatment preferences [53, 325, 326]. Other explanations for doctors not enrolling eligible patients include time constraints, concern that the doctor/patient relationship may be adversely affected, dislike of open discussions that involve uncertainty, perceived conflict between the roles of researcher and doctor, and loss of professional autonomy [327].

Patients may also decline to participate in the study. They may not want to be part of an “experiment”, may have an aversion to one or other of the treatments being assessed, perceive that they are too old or unwell to participate, or they may be unwilling to commit to additional visits and monitoring [325, 328, 329].

The prevalence of risk factors may be different for trial participants compared with non-participants as a result of selection beyond the eligibility criteria [330, 331]. Patients who decline to participate in clinical research studies are often at increased risk of disease or mortality compared with those who participate [331-333]. Petersen and colleagues [334], for example, found a significant difference in prognostic factors and clinical outcomes between eligible consenters and eligible non-consenters when they assessed the generalisability of a trial for a new recovery programme for hip replacement surgery. Their findings highlight the importance of reporting information about the pathway to recruitment, including how patients are referred, investigated and diagnosed, and how they are subsequently selected and excluded [335]. With the availability of this information, doctors are better able to characterise the population to whom the trial results may be applied. However, discussion of the determinants of external validity in trial publications is often inadequate [248, 261, 335, 336].

Doctors conducting the research may themselves be unrepresentative. Study investigators may have a special interest in the topic under study or be enthusiasts, innovators or early adopters [300]. Using the example of a large study of patients receiving epidural pain relief after surgery [337], Myles and Rigg [338] highlighted the potential for the skill and knowledge of the anaesthetist to confound the results of a trial. In their study, patients received epidural pain relief for an average of three days after surgery. However, the infusion was discontinued
prematurely in 19% of cases due to mechanical problems, including dislodgment of the catheter and kinking, disconnection and occlusion of the infusion pump. The authors intended to remedy these problems with further education for staff. The authors suggest that variation in the level of skill and knowledge of the anaesthetist and other staff involved in the care of these patients introduced additional confounding to the study that may limit the generalisability of the results.

Participating doctors may be chosen according to their track record [53]. Surgeons who were selected to participate in the Asymptomatic Carotid Atherosclerosis Study (ACAS), for example, were required to have extensive experience and a good safety record, with a low rate of adverse outcomes following surgery for occluded carotid arteries [339]. The study compared medical management with surgical management of asymptomatic patients known to have occluded carotid arteries. The outcome of the study was in favour of the surgical approach. In large part, this benefit was attributed to the low operative risk accomplished by a select group of highly experienced surgeons. With respect to the generalisability of the study, the investigators recommend that before referring asymptomatic patients for surgery, doctors ensure that the surgeon has a similar level of experience and a track record comparable with the surgeons who participated in the study [339]. Citing investigations by Hovorka et al. [340] and Merry et al. [341], Horan [49] provides support for the proposition that the patient’s outcome can be influenced by the individual giving the anaesthetic. The author cautions readers against “assuming that equally good outcomes are achievable by all, especially where study procedures require personal skill, dexterity or decision-making” [49 p. 679].

Lastly, the study setting may be dissimilar. Geographic differences in methods of treatment, natural history of disease or racial differences in susceptibility to disease can all affect the generalisability of a study [53, 342]. Estimates of death and disability following surgery, for example, are known to vary several-fold between hospitals and healthcare systems even after adjusting for known confounding variables [112, 343-348]. This observation could relate to cultural, demographic, socioeconomic, and political differences between patient groups or differences in hospital practices and healthcare investment, which vary between healthcare settings. Though the actual reasons for the differences in complication rates remain speculative [116, 349], these factors all affect population health and healthcare outcomes differently [141, 336, 350].

Another facet of the study setting relates to the funding and ownership of the hospitals that conduct clinical trials. Both funding and delivery of healthcare can be public or private [351]. Privately funded patients are absent from most RCTs in the UK [300]. Similarly, in Downs’
systematic review of the safety and effectiveness of gall bladder surgery, all 15 trials were based at university teaching hospitals [352]. In America, the College of Surgeons’ National Surgical Quality Improvement Program (NSQIP) [353], is one of the largest sources of information on the risks following surgery. However, the data may not be applicable outside of the US. As part of the programme, detailed information about patients’ outcomes after surgery is collected from all Veterans Affairs Hospitals [354]. Patients treated in these facilities tend to be older males, and although the NSQIP now includes private sector hospitals [355], most of the participating medical centres to date have been large academic centres [61]. These institutions are often assumed to be early adopters of new medical technologies and techniques [356, 357] so the data may not yet be applicable to other hospitals and those outside of the US.

Teaching methods and training outcomes, which vary between settings, may also be contributory [358]. Sites and colleagues [359] studied the incidence of local anaesthetic toxicity and nerve injury following regional anaesthesia. Symptomatic pneumothorax did not occur in any of the 12,668 anaesthetic procedures despite previous research reporting it as a complication [360]. Barrington [358] speculates that the local culture and a strong commitment to training and education in the latest techniques and effective training methods for novices may have been contributory. However, most studies are not sufficiently detailed to allow further exploration of outcomes according to patient and hospital characteristics, which may vary geographically.
### Table 12. Clinician-, patient-, healthcare setting- and treatment-related differences between clinical studies and routine clinical practice.

<table>
<thead>
<tr>
<th></th>
<th>Clinical study</th>
<th>Routine practice</th>
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</thead>
<tbody>
<tr>
<td>Clinician-related</td>
<td>Investigators conducting the research may have a particular interest in the topic, may be highly experienced or be enthusiasts and innovators [300].</td>
<td>Healthcare teams are rostered to care for patients irrespective of special interests</td>
</tr>
<tr>
<td>Patient-related</td>
<td>May exclude patients with compromised kidney function women [309, 310], the very young [311, 312] and very old [313-316], those on medications potentially interacting with the study medication/s, ethnic minority groups [317, 318], patients with multiple pre-existing medical conditions [319, 320] including psychological conditions or those with a history of illicit drug or alcohol abuse [321]. Members of ethnic minority groups for whom language, cultural factors, and beliefs about medical research may be significant barriers to recruitment, are not commonly enrolled [325].</td>
<td>Complicated and severely ill patients are not excluded from everyday practice [295]. Language and cultural factors do not preclude patients from receiving treatment.</td>
</tr>
<tr>
<td>Healthcare setting-related</td>
<td>Often conducted in large academic centres that are assumed to be early adopters of new medical technologies and techniques [356, 357]</td>
<td>Local hospital setting</td>
</tr>
<tr>
<td>Treatment-related</td>
<td>Patient care is directed by study protocol [301, 302]</td>
<td>Patient care is directed by the healthcare team and local hospital practices</td>
</tr>
<tr>
<td></td>
<td>Patients may undergo additional laboratory tests, imaging or consultations with other specialists [303].</td>
<td>Methods of diagnosis and treatment are employed at the discretion of the healthcare team</td>
</tr>
</tbody>
</table>

### 2.7.6 RCTs in anaesthesia and surgery

Although well-executed RCTs yield the most reliable information about clinical outcomes following surgery, evidence from these studies is often lacking for questions about rare and time-delayed adverse outcomes after surgery. Because many perioperative outcomes occur infrequently [54, 295, 305], large numbers of patients are required to achieve enough statistical power to detect a clinically important effect [289]. Individual studies are often too small to detect measurable differences in events such as death after surgery, and cannot attribute observed differences to any single intervention or an accumulation of effects [32, 295, 350]. Underpowered studies in anaesthesia and the related fields of perioperative and pain medicine have been reported [289, 361, 362], and sample size calculations are often based on unrealistic effect sizes [363] with the result that studies are likely to miss a true treatment effect and authors make conclusions which are not supported by their findings [338]. Statistically significant trials with small sample sizes may demonstrate substantial
fragility and subsequently turn out to be inaccurate [364-366]. Recruiting large sample sizes may overcome many of these problems, but significant resources are required to conduct large RCTs [367] and this is likely to contribute to the number of small, underpowered studies.

RCTs may also be impractical for the study of time-delayed treatment or disease-related effects that may not materialise until months later, often well beyond the follow-up period of many conventional studies [300]. Although little is known about the effects of anaesthesia on long-term outcomes, most serious events after surgery are not attributed solely to anaesthetic management and there are significant challenges to tracking patient outcomes in the longer term [112, 338, 349]. This has led to the study of more minor events that occur early in the recovery phase, including relief from pain and nausea and vomiting [338]. However, surgery affects many aspects of patients’ lives, including their quality of life and independence, that are not visible from the vantage point of the operating rooms [349]. This observation has led some authors to advocate for long-term patient follow-up to appropriately assess outcomes after surgery [349, 368].

Information on intermediate and long-term outcomes such as mortality, cognitive dysfunction and pain, for example, is captured infrequently. Previous studies suggest that cognitive dysfunction may persist in some patients for months or years after surgery [369-371]; that a high percentage of postoperative complications and deaths occur after hospital discharge [372]; and that a range of operations are associated with chronic pain syndromes [373]. The occurrence of a complication within 30 days of surgery is thought to be one of the strongest determinants of long-term survival for patients undergoing major surgery [244]. In their study of adult patients undergoing major non-cardiac surgery with general anaesthesia, Monk and colleagues [112] highlighted the association between low blood pressure during surgery, anaesthetic depth and 1 year mortality. The authors concluded that anaesthetic management during surgery may have a greater effect on long-term outcomes than was previously anticipated. However, studies (both experimental and observational) that require prospective data collection about large numbers of patients are resource-intensive [367]. Large-scale, long-term studies are often impractical for the study of rare or long-term treatment effects because of financial constraints, low compliance rates, or high rates of participant withdrawal [248].

2.8 Closing the research-practice gap: Making the case for RCD in the learning healthcare system

In the preceding subsections, we have seen that systematic reviews of rigorous RCTs provide the best evidence on the effectiveness of interventions. At the same time, however,
disentangling the effects of the intervention from the influence of contextual factors is one of the most challenging aspects of interpreting the results [374]. Many clinicians struggle to apply new knowledge from these studies, since most evidence has been produced by clinical research involving patients who differ from their own and who were treated in highly controlled research settings [57, 58].

The increasing implementation of EBM is set to become one of the most challenging endeavours for clinicians yet. The rapidly growing production of healthcare information increasingly leads to a situation of information overload. It is now impossible to read the ever-increasing number of guidelines or much less apply them [375, 376], and the plurality of advice is unhelpful and confusing [375]. Increasing patient and treatment complexity compounds the issue of how best to apply findings from primary studies [376, 377]. As the population ages and the prevalence of chronic degenerative disease grows, anaesthetists will increasingly be faced with caring for older patients with multiple medical conditions (multimorbidity) [86, 87, 378]. Balancing the benefit and harm of recommended treatments in patients with multimorbidity is difficult because evidence is almost entirely based on trials of interventions for single conditions, from which people with multimorbidity are largely excluded [379]. With an ever-mounting burden of disease, the number of treatment options for various conditions and sequences in which the options are applied has grown exponentially. Many of these treatments may be tested in separate studies, “leaving few data on the chains of conditional probabilities that link sequences of tests, treatments, and outcomes” [298, p.840]. This markedly increases the chances of differential responses to the same treatment. Together these issues manifest the unidirectional relationship between research and practice (i.e. research findings are applied to practice using EBM) [380] and illustrate the “research-practice gap” – the situation in which evidence may not attend to the needs of those who might use it.

In an attempt to redefine the relationship between research and practice as bidirectional, The National Academy of Medicine (NAM, formerly the Institute of Medicine) put forward the concept of the learning healthcare system (LHS). In 2007, NAM released the first report entitled *The Learning Healthcare System*, in what is now a series of reports that describe a new conceptual approach for bridging the gap between clinical research and everyday clinical medicine. NAM coined the term LHS to refer to a system in which:

*Science, informatics, incentives and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the*
delivery process and new knowledge captured as an integral by-product of the delivery experience. [381, p.xi]

The underlying concept is straightforward: “harness the power of data and analytics to learn from every patient, and feed the knowledge of what works best back to clinicians and patients to create cycles of continuous improvement” [382, p.1]. Consistent with the characteristics of cyclical improvement processes in general, LHS can be thought of as a closed-loop cycle in which scientific evidence informs clinical practice (EBM) while data gathered as part of routine clinical practice informs scientific investigation (commonly called evidence-generating practice or practice-based evidence). Professor Charles Friedman, a well-respected advocate of the LHS movement, suggests that LHSs generally share four core attributes:

1) every patient’s characteristics and experience are available for study, 2) best practice knowledge is immediately available to support medical decision-making, 3) improvement is continuous and occurs routinely, economically and almost invisibly and 4) all of the above is part of the culture. [383]

Beyond these characteristics, there is no single LHS. Rather, Friedman argues, there are many manifestations that range in scale from a hospital department that tracks outcomes for its patients in order to learn and improve its practice, to an institution that builds predictive models from data captured in its electronic health record (EHR), to a national network that aggregates vast numbers of patient records from multiple institutions to assess the effectiveness of a given treatment. The LHS imperative is founded on the premise that the discovery of new knowledge is a natural outgrowth of patient care [384] and that this shift in thinking enables rapid and efficient advances in healthcare knowledge that are highly relevant to everyday practice [380, 385, 386].

The structure of the LHS is commonly represented as a cycle that stitches together the social, organisational and technical facets of learning [382]. The closed-loop, five-step learning cycle as described in Friedman’s paper “Toward Complete and Sustainable Learning Systems” [383] is contrasted with the open-loop learning cycle that is commonplace in much of healthcare (Figure 14). The complete virtuous cycle (right) is comprised of an afferent (blue) side in which relevant data about a problem of interest are assembled and analysed before being interpreted at the intersection of the afferent and efferent sides. Following interpretation, the cycle continues along the efferent (red) side to feed back into the system what has been learned and to take action to change practice. The blue/afferent side is underpinned by technical innovations, such as widespread adoption of EHR, but the red/efferent side represents that development which is social, organisational, ethical and
political in nature [387, 388]. The open-loop cycle (left) shares many of these features, but falls short on the task of incorporating results into practice. The LHS is founded on the premise of the complete closed loop in which both technical and social methods are used to learn and improve with each and every patient who is treated [388].

RCD are considered the staple of the LHS. Although loosely defined (see Crombie [59]), RCD are widely considered to include clinical and sociodemographic data from a variety of sources including EHR, laboratory information systems, pharmacy and radiology systems, and administrative data for billing purposes [60, 389, 390]. Whereas primary datasets (such as those obtained from formal clinical research) contain information that has been prospectively collected for a specific purpose [391], RCD are gathered as part of routine patient care outside of the research setting and so reflect the actual, everyday experiences of patients [61]. A 2010 NAM report entitled *Clinical Data as a Basic Staple of Health Learning* distilled a number of discussions on the use of data gathered during the course of routine patient care as one of the building blocks of the LHS [390]. Although results from RCTs are well-established as the “gold standard” of evidence for assessing the effectiveness of healthcare interventions, there has long been concern that these trials may not truly represent the future population of patients to whom the results will be applied [53]. There is therefore enormous potential for data gathered directly from the patient care environment to be used “to gain actionable insights into the best ways to treat the patients in the care system that generated the data” [57, p.2163].

Using RCD to investigate clinical questions confers a number of advantages (Table 13) and RCD possess many of the attributes of quality data (see [392]). For the most part, data are
already available. Many and diverse data are prospectively collected to fulfil everyday administration requirements or as an integral part of everyday clinical practice [393, 394]. Because the structures for data collection already exist, this approach is unobtrusive, timely [392] and relatively low-cost [395]. RCD are especially cost-effective for the study of rare or time-delayed treatment effects that require data collection over a prolonged period of time [396]. In addition, non-randomised treatment comparisons based on RCD are often suggested to have greater external validity compared with many RCTs [53]. There are several reasons for this suggestion. RCD permit the identification of large numbers of patients because data are captured for all patient-provider interactions [394]. These data reflect everyday clinical practice in large, unselected patient groups, in effect permitting the study of real-world representative populations that include the effects of the doctor-patient relationship and patient treatment preferences [53, 56, 61, 300]. RCD also have the advantage of being collected before or in ignorance of the outcome of interest [397, 398], thereby delivering potential reduction in recall, selection and non-response biases. The use of data captured about large numbers of patients, over extended periods of time as part of routine clinical/administrative practices, represents one approach to improved generalisability of findings.

The strengths of large, readily available datasets must be tempered by the increased likelihood of confounding [399, 400]. According to Rosenberg, [61], confounding arises when a differential distribution of extraneous variables exists between groups of patients in a study. Both confounding variables, as well as known, measured variables, are associated with the outcome and risk factor/s of interest. It follows that the presence of confounding variables may result in a biased estimate of the effect of exposure on the outcome variable [61]. As available data are limited to that which is routinely collected, information about potential confounding variables may be absent or imperfectly captured in RCD. The absence of information about non-prescription and over-the-counter medications [401], alcohol or substance use [393], and imperfect information about smoking status for which neither duration nor severity is readily captured [402], may confound outcomes under investigation in anaesthesia and surgery [403-405]. Multivariate statistical models and propensity score methods [406] are frequently employed to adjust for confounding by measured variables. However, sophisticated statistical techniques cannot adjust for confounding by unmeasured or omitted variables so the likelihood of residual confounding in RCD remains [61, 407-409].

In the absence of rigorous standards used to measure and record data, studies (see [410-412]) have questioned the completeness and reliability of RCD used for outcomes research. These
data may comprise unstructured information in the form of clinical narrative, or structured information about patient demographics such as age, sex, and ethnicity, in addition to clinical information about a given encounter in the form of dates and International Classification of Diseases (ICD) [413]-encoded diagnoses [414]. ICD codes are frequently used to adjust for a priori risk of adverse outcomes or to denote adverse outcomes, such as complications of care or iatrogenic effects [415]. Incomplete or incorrect coding of these data affects the validity of risk adjustment models [62] and the accuracy of comparisons between study groups [416]. The accuracy and reliability of these codes in describing diagnoses, procedures, characteristics of individual patients and adverse events has been repeatedly questioned [417, 418]. Limited diagnostic coding reduces the information available to investigators about the severity of patients’ pre-existing medical conditions. For example, studies have shown that some pre-existing conditions such as diabetes and high blood pressure are often not coded in cases where the patient is suffering from a more severe illness [419, 420]. Imprecise coding also limits investigators’ ability to make temporal distinctions between existing comorbid conditions and those arising as complications of care [391, 421]. Non-uniform coding practices between assessors and institutions [412] over time further compound issues of reliability [61, 420].

Despite these limitations, the use of RCD may represent an adjunct approach to identifying, quantifying and understanding the risks and benefits following surgery and anaesthesia. Extracting and analysing these data permits the study of associations between surgical and anaesthetic care, and perioperative outcomes in non-experimental settings, and may provide anaesthetists with a valuable source of generalisable information about risks of undergoing surgery. Only with a greater willingness to analyse these data is it possible to achieve a realistic understanding of how observational studies and in particular, RCD, can best be utilised [422].
Table 13. Strengths and limitations of using RCD to investigate clinical questions.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>Relatively low cost because structures for collecting data already exist [394]</td>
<td>Available data limited to that which is routinely collected. Relevant data of interest (i.e. potential confounders) not collected</td>
</tr>
<tr>
<td>Improved generalisability of findings and reduced potential for recall, selection and non-response biases [393, 394]</td>
<td>Potential misclassification of comorbidities, procedures and diagnoses</td>
</tr>
<tr>
<td>Data collected over extended period of time [394]</td>
<td>Diagnostic data often not available (i.e. severity of underlying illness)</td>
</tr>
<tr>
<td>Breadth and diversity [394]</td>
<td>Data quality and integrity may differ across data sources and over time</td>
</tr>
<tr>
<td>Datasets often contain data on many individuals and can therefore yield large cohorts</td>
<td></td>
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<tr>
<td>Can be used to answer a variety of research questions</td>
<td></td>
</tr>
<tr>
<td>Useful in assessing rare or long-term outcomes [393, 394]</td>
<td></td>
</tr>
<tr>
<td>Collection is unobtrusive because data are collected as part of everyday clinical practice/administration requirements</td>
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2.9 Enabling the LHS through BI

A highly participatory LHS can be developed in part from meaningful use of RCD that are enabled by BI. The term BI first appeared in the seminal work of IBM researcher Luhn in the late 1950s. Luhn [64p. 314] defined business as a “collection of activities carried out for whatever purpose, be it science, technology, commerce, industry, law, government, defence, et cetera”; an intelligence system as “the communication facility serving the conduct of a business (in the broad sense)”; and intelligence as “the ability to apprehend the interrelationships of presented facts in such a way as to guide action towards a desired goal.” Three decades after Luhn, Howard Dresner of the Gartner Group popularised BI as an umbrella term to “describe concepts and methods to improve business decision-making by using ‘fact-based systems’” [65, para 22]. It was not until the late 1990s that Dresner’s definition became widespread, however, during which time the IS discipline spawned a collection of papers on applications and technologies for gathering, storing, accessing and analysing data [423-428]. More recently, the focus of the IS research community has shifted away from the design, development and implementation of individual BI systems. Instead, the discipline has adopted an holistic view of the subject in which BI technologies are embedded in the fabric of the organisation to help discover new knowledge from raw data [429, 430].

For the purpose of this thesis, BI is conceptualised as a process, a product, and a set of technologies. Drawing on the definition of BI offered by Negash [2 p. 180] in his paper in the *Communications of the Association for Information Systems*, BI encompasses “the continuous
processes for transforming data into useful information; the technologies used to support these processes and the knowledge gained through human analysis and interpretation of the resultant information”. The reasons for defining BI as a composite of process, technology and product are twofold. First, this definition fuses key elements – the so-called building blocks [431] – of BI set out in leading IS journals. Since the mid-2000s, a number of publications in leading IS journals have adopted a broad, three-dimensional definition of BI. Carte and colleagues’ paper on the advanced state of BI at Cardinal Health in the US in the 2005 special issue of MIS Quarterly, defined BI as a product – “the accumulated knowledge about the organisation, its operations, and to a lesser extent its immediate business environment” [432 p. 413]. The authors expanded on their in-text definition with a footnote in which BI was further defined as the act of collecting data, analysing the data to detect patterns and meanings within the data, extracting information from these analyses, and turning this information into actionable knowledge [432 p. 413]. Only two years later, publications by Davenport [433] in the Harvard Business Review, Clark, Jones and Armstrong in MIS Quarterly [434] and March and Hevner [435] in Decision Support Systems all described BI at the intersection of processes, technologies and information outputs. Watson and Wixom [436] in their IEEE Computer paper “The Current State of Business Intelligence” proposed a BI framework that included two primary activities – data warehousing or “getting data in” and BI “or getting data out” – supported by technologies for extracting, loading and transforming data and reporting and predictive analytics. The authors’ deliberate division of data warehousing from BI provides a strong signal to readers that BI is as much about the technologies and processes to extract, transform and load data from source systems as it is about reporting and analytic processes, and technologies to transform this data into informational outputs. Even as some authors have extended the term BI to business intelligence and analytics (BIA) and, more recently, included big data, its essence remains unchanged. Lim and colleagues, for example, in their paper on research directions in BIA in the ACM Transactions on Management Information Systems, described BIA as the “development of technologies, systems, practices and applications to analyse critical business data so as to gain new insights about business and markets” [437 p. 17]. A broad definition of BI that accommodates the processes, technologies and their outputs recognises the evolution of the term and is consistent with current thinking in leading IS publications.

BI has emerged as an important domain of enquiry for both IT practitioners and researchers, reflecting the size, scale and consequence of data-related problems that plague modern-day organisations [66]. Across several industry sectors, organisations have leveraged business data to increase productivity, gain competitive advantage and transform business models
Leading e-commerce vendors Amazon and e-Bay have revolutionised the marketplace with their highly innovative e-commerce platforms and product recommendation systems. Governments of countries that are leaders in ICT have initiated big data application projects to enhance economic growth, engagement in public affairs and national security. The Singapore government, for example, launched the Risk Assessment and Horizon Scanning (RAHS) programme within the National Security Coordination Centre to proactively manage national threats, such as terrorist attacks and infectious diseases [438]. In the banking sector, Hu and colleagues [439], analysed systemic risk in banking systems to develop a network approach to risk management with the aim of predicting “contagious” bank failures. Their paper was published in the 2012 MIS Quarterly special issue on BI research. In the same special issue, Abbasi and colleagues [440] used design science to develop MetaFraud, a novel meta-learning framework for enhanced financial fraud detection. The authors acknowledged that although there has been a concerted effort to develop automated approaches for fraud detection, the domain continues to be an important challenge for BI technologies. In summary, a wide range of domains have demonstrated the capacity to leverage data, systems and human interconnectedness to enhance business decision-making.

However, attempts to employ BI to realise transformative impacts in the context of healthcare have not enjoyed similar success. While the sector may tout widespread use of EHR [441, 442] as an example of IT-enabled transformation, it has not undergone the same type of transformation that is pervasive in other industries [74, 382, 443]. Chute and colleagues attribute the slow adoption and the comparative immaturity of BI to the complexity and heterogeneity of biomedical, operational and clinical data [444]. Parmanto et al. [445] point out that since healthcare data is primarily encounter-based, patient data is modelled as a “value circle” [446] rather than a traditional, linear, value-chain in which a product is transformed from raw material to finished goods as it moves through a series of steps that are part of a well-defined manufacture process. Connell and Young [447] describe the tension between the interpersonal and the interactive, arguing that the complexity of internal and external source systems in healthcare demands more person-to-person knowledge transfer compared with other industries. Madsen [448] highlights the difficulty associated with inclusion of non-standard, subjective, contextual data and the lack of a common worldview in the healthcare sector. The combination of these factors has no doubt contributed to a paucity of research to guide BI systems development and implementation [74] and the common conceptualisation of BI as a mere technology system designed to deliver decision-support information [74]. However, with the growing number and sophistication of healthcare

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technologies, the issue of how healthcare data are utilised to support evidence-based decision-making has become increasingly important and is an area ripe for innovative research.

In the previous paragraphs I have established a conceptualisation of BI before returning to the subject of RCD and LHS to conclude this subsection. Although the healthcare literature on RCD and LHS does not explicitly refer to BI, nor does the IT/IS literature explicitly refer to RCD or LHS, and BI and LHS share a common goal of transforming raw data into actionable insight. Nowhere is this more apparent than in the literature on the big data movement. Big data is characterised by use of RCD that are significant in volume, veracity, velocity or variety [449] to study complex problems, and there is growing recognition of the benefits of its application to both healthcare [450, 451] and business [66]. But to quote Sacristan and Dilla, [452, p.1014] “there is no big data without small data [because] learning healthcare systems begin and end with the individual patient”. Small data is RCD. It is data in a volume and format that makes it accessible and actionable and is less about mass processing of petabytes of unstructured records and more about decentralised wrangling of small pieces of loosely joined data [453].

BI is the stuff of small data. In his work on the support structures necessary to enable complete and sustainable learning systems [383], Friedman argues that a scalable infrastructure that makes learning effective, sustainable and routine is needed to support complete, closed-loop learning cycles in the LHS. He illustrates the components of the complete platform required at each stage of the virtuous learning cycle, which I have adapted in Figure 15. The relationship between BI, LHS and RCD is clear. If BI encompasses the continuous processes for transforming data into useful information, the technologies used to support these processes, and the knowledge gained through human analysis and interpretation of the resultant information [2 p. 180], then BI affects or is effected by every step in the virtuous learning cycle. From the systems understanding and data warehousing technologies required to extract and clean RCD in EHRs to the domain knowledge and data visualisation technologies required for exploration, interpretation and presentation of results, BI is as an enabler of closed-loop virtuous cycles for evidence-generating medicine in the LHS.
2.10 Discussion

BI in healthcare is organised around the concept of the virtuous cycle in the LHS. The concept of the LHS arose from concerns about an ever-widening gap between clinical research and clinical medicine. A LHS is a system that seeks to learn from each and every patient, and to feed knowledge of what works best and when back to clinicians to create virtuous, closed-loop cycles of continuous improvement [382]. RCD are a basic staple of the virtuous cycle and the LHS at large. Although results from RCTs are well-established as the “gold standard” of evidence for assessing the effectiveness of interventions, there has long been concern that these trials may not truly represent the population of future patients to whom the results will be applied. Concerns about the generalisability of findings from RCTs and the increasing adoption of EHR have seen many authors turn to the use of data gathered during the course of routine patient care to transform health and healthcare. Because new knowledge is a natural outgrowth of patient care in the system that generated the data, this knowledge is timely, representative and therefore highly relevant to everyday practice. As well as helping to generate knowledge, the LHS is also focused on the task of incorporating knowledge into practice and therefore a scalable infrastructure is needed to support closed-loop learning cycles. With the goal of transforming raw data into actionable insights, BI effects and is affected by every step in the virtuous learning cycle. From the systems understanding and data warehousing technologies required to extract RCD to the domain knowledge and data visualisation technologies required for exploration, interpretation and presentation of results,
BI is therefore an enabler of closed-loop virtuous cycles for evidence-generating medicine in the learning healthcare system.

In the context of preoperative anaesthetic assessment, the use of RCD through virtuous cycles may represent an adjunct approach to identifying, quantifying and understanding the risks and benefits following surgery and anaesthesia. Extracting and analysing these data permits the study of associations between patient- and surgery-specific risk factors and perioperative outcomes in non-experimental settings and may provide anaesthetists with a valuable source of generalisable information about the risks following surgery and anaesthesia. However, healthcare lacks a mature approach to integrating, analysing and leveraging RCD to derive insight. There is a dearth of literature on the subject of how one might go about using RCD to provide actionable insights to healthcare professionals, what that journey might look like and how an ISD framework can be used to support that journey. The absence of a body of literature on this subject represents a significant gap in knowledge.

2.11 Conclusion

This chapter has surveyed the relevant literature to provide a base for understanding the research problem under investigation. The research problem suggests that current BI capability in preoperative care does not provide anaesthetists with sufficient actionable insights relevant to their own clinical settings in support of risk-benefit assessment before elective surgery. This chapter has reviewed literature on the subjects of preoperative anaesthesia assessment, including the assessment of risks and benefits following surgery. Additionally, it has canvassed the subject of the LHS using RCD and BI with a view to providing anaesthetists with valuable information about perioperative outcomes and risk in the healthcare system that generated the data. In subsequent chapters, the literature will be further used to aid contextualisation and understanding of the research that was undertaken to meet the objectives and solve the research problem. This research included the development of a BI prototype for use in preoperative care (the first objective), understanding the nature of the work of risk communication (the second objective), and describing mortality rates after surgery to assess the value of using RCD in this setting (the third objective). Whereas RCTs are necessary to establish causality, qualitative research methods, which emphasise interpretation, pragmatism and participation are employed in the exploration of a problem that has not been subjected to in-depth study. With little understanding of the nature of BI in preoperative care, the case for use of exploratory, qualitative, PAR is presented in the chapter that follows.
Chapter 3: Research design

3.1 Introduction

In Chapter 2, the themes that underpin this research were summarised and the reader was orientated to the nature and significance of the research problem through the conducting of a literature review. Briefly, the research problem suggests that the current BI capability in preoperative care does not provide anaesthetists with sufficient actionable insights relevant to their own clinical settings in support of risk-benefit assessment before elective surgery. This chapter is concerned with the research design that was employed in an attempt to solve this problem. This chapter is structured as follows. First, I describe the dominant research paradigms and the rationale for situating this thesis in the interpretive and pragmatist paradigms. This section is followed by an overview of action research (AR), and more specifically participatory action research (PAR) as the strategy of enquiry. Next, I describe the techniques for data collection and analysis used within the PAR process before addressing the ethical considerations inherent in this research. This chapter concludes with a discussion of the limitations of AR and the steps I took to ensure a rigorous approach to this research.

3.2 Research paradigm

All research is based on a set of beliefs about knowledge and how to acquire it, and about the physical and social world [454, 455]. Chua [456 p. 604] formulates three sets of beliefs that “delineate a way of seeing and researching the world:” (1) beliefs about the notion of knowledge, (2) beliefs about the phenomenon or “object” of study, and (3) beliefs about the relationship between knowledge and the empirical world. Different positions in relation to these beliefs are seen to constitute the worldview or research paradigm that social scientists adopt in the conduct of their research [457]. The researcher must be clear about these underlying beliefs if the research is to be conducted appropriately and evaluated accordingly [458].

The underlying paradigms for this research are interpretivism and pragmatism. In the subsections that follow, I describe the interpretive and pragmatic paradigms and provide the rationale for combining the two. Chua [456] and subsequently Orlikowski and Baroudi [457] and Lincoln and Guba [459] have provided valuable descriptions of the critical, positivist and post-positivist paradigms as alternative worldviews for IS research.

3.2.1 Interpretivism

Interpretive studies assume that our “knowledge of reality is gained only through social constructions such as language, consciousness, shared meanings, documents, tools, and other
People derive meaning from their interactions with the world around them and therefore the goals of interpretive research are to understand phenomena through the meanings that people assign to them. Interpretive researchers reject all forms of absolutism, adopting instead a non-deterministic perspective to obtain a relativistic understanding of phenomena through human sense-making. In IS, interpretive studies aim to produce an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context. Hence, interpretive researchers seek to understand the context of a phenomenon, since the context is what defines the situation and makes it what it is. Other characteristics of interpretive studies include evidence that the phenomenon of interest is examined in its natural setting through prolonged fieldwork and from the perspective of the individuals under study. The interpretive researcher seeks to gain an overview of the research context that is “holistic” (systemic, encompassing, integrated) comprising of its logic, its arrangements and its explicit and implicit rules. More extensive discussions of the nature of interpretive research in IS can be found in Walsham, Myers and Klein and Myers.

### 3.2.2 Pragmatism

As an alternative to positivist and anti-positivist positions in the literature (see Baskerville, Goles and Hirschheim and Wicks and Freeman), pragmatism holds that both the meaning and truth of an idea is a function of lived experience and practical outcome. It follows that the pragmatist is concerned with “asking the right questions, and getting empirical answers to those questions.” Pragmatism gives the researcher licence to use “whatever philosophical and/or methodological approach works best for the particular research program under study.” Contingent as the approach may be, it does not mean that anything goes. According to Goles and Hirschheim, what works best or is most useful is that which is instrumental in producing desired or anticipated results. Wicks and Freeman elaborate on this point with their definition of usefulness in the pragmatic sense:

*Usefulness simply requires those engaged in research or decision-making to scrutinize the practical relevance of a set of ideas as defined by their purposes and those shared by their community (e.g. within a country, a corporation, a research stream).* [469 p. 15]

Goldkuhl illustrates the meaning of pragmatism for the field of IS research. He identifies five features of pragmatist studies in IS: (1) there is a focus on actions in empirical enquiries, but also (2) the broader practice context is considered; (3) abstractions that are not grounded in practical reality are avoided; (4) the aim is to develop knowledge that improves
actions and practices, requiring that researchers take part in changing and improving the world rather than acting as disinterested observers; and (5) that interpretation is necessary but not sufficient – studies must use pragmatic instruments to evaluate which actions worked and which did not.

Baskerville and Myers [471], in their introduction to the 2004 special issue on AR in MIS Quarterly, identify pragmatism as the philosophy shared by most forms of AR in IS. Drawing on the works of Peirce [475], James [476], Dewey [477, 478] and Mead [479], they describe the four key AR premises that arise from pragmatist philosophy:

-Peirce’s tenet that all human concepts are defined by their consequences;
-James’ tenet that trust is embodied in practical outcome; Dewey’s logic of controlled inquiry, in which rational thought is interspersed with action and
-Mead’s tenet that human action is contextualized socially, and human conceptualization is also a social reflection. [471p. 331]

The authors elicit the characteristics of AR in reference to these four premises, further emphasising the pragmatist nature of AR in the field of IS.

More extensive discussions on the subject of pragmatism can be found in Howe [480], Cherryholmes [481], Reichardt and Rallis [482], Murphy [483] and Rorty [484]. The literature on mixed methods research provides an especially valuable resource (see, e.g., Tashakkori and Teddlie [472, 485]). Specific to IS research, Hirschheim [486] takes an historical perspective to IS epistemologies, briefly describing the influence of James, Peirce and Mead. The treatment of pragmatism in IS is further described in Goldkuhl [487] and the combination of interpretivism and pragmatism in IS research is discussed in Marshall [488].

3.2.3 Rationale for combining interpretivism and pragmatism

Research is a particular form of enquiry, concerned with seeking solutions to problems and answers to questions. According to Gillham [489 p.3], “the raw material of research is evidence, which then has to be made sense of”. Assumptions about what constitutes evidence and how this evidence can be known are represented in the researcher’s choice of paradigm. It follows that the decision to study a topic in a particular way always involves some kind of philosophical stance about what is important [490].

The choice of research paradigm for this thesis reflected the need to appropriately address the research problem [491]. The research process was emergent and the research problem (and subsequently methods) evolved with the research process (discussed later). As a consequence, the research problem required a balance between intervention and understanding obtained through enquiry, and field study to yield knowledge that was both interesting and constructive.
(see Goldkuhl [474]). This thesis contributed to local improvements through intervention, requiring continual exploration and learning with the aim of generating constructive knowledge for everyday clinical practice. However, it also required an appreciation of participants’ meaning-universes and professional languages, as well as the interpretation of social constructs (again see Goldkuhl [474]). Accordingly, this research is couched in the pragmatist and interpretivist research paradigms.

(Functional and methodological) pragmatism (see Goldkuhl [487] for a discussion of the types of pragmatism in IS research) is adopted as the base paradigm and elements from the interpretive paradigm are used in a supportive fashion. I draw heavily on Goldkuhl [474] for much of the rationale for this approach. In his paper on the combination of pragmatism and interpretivism in IS research, Goldkuhl [474] argues that pragmatist thinking has played an important, though largely implicit, role in ISD research (see, e.g., Braa and Vidgen [492, 493]). The research process is undoubtedly concerned with change, action and reflection, and the knowledge that results from the interplay between these three aspects. As an intervention, ISD is instrumental in co-constructing knowledge that may be useful for local practices as well as general ones. The knowledge forms produced by the research process are not restricted to explanations (as in positivism) or understanding (as in interpretivism). Rather, ISD produces diverse forms of prescriptive (as in guidelines), normative (exhibiting values) and prospective knowledge (suggesting possibilities) [474]. Indeed, the act of developing an IS embodies the very essence of the pragmatist philosophy – to be helpful to the world. Goldkuhl [474] goes on to identify pragmatism as an appropriate basis for research processes that intervene in the world, rather than merely observe it. It follows that this research – which involved developing a BI prototype to gain actionable insights into perioperative outcomes at the request of local stakeholders – was (appropriately) grounded in pragmatist thinking.

However, IS do not exist in a vacuum; their development shapes and is simultaneously shaped by the social and organisational context [494]. Modern healthcare systems are incredibly complex social and organisational entities. They are characterised by “a high degree of professional specialization, marked division of labour, and an interdependence among relatively autonomous healthcare providers” [495 p.53]. I reasoned that the design and development of the BI prototype would be no less complex because ambiguity and uncertainty are salient aspects the development process [496]. Adopting an interpretive approach towards this research also permitted the discovery, and ultimately revelation, of those organisational, technical, social, professional and therapeutic aspects that shape and are shaped by the course of ISD (and more specifically, BI) in healthcare [497]. This allowed for
a focus on the real-life “messy” reality of healthcare work and BI development in action [498].

At this point it is fitting to state the reasons for not situating this research problem in the (post-)positivist traditions of natural science. I draw on Susman and Evered’s [499] work for this rationale. The authors summarise the differences between positivist science and AR before considering the question of which approach is better. They identify the positivist paradigm as a poor choice when the unit of analysis is a “self-reflecting subject, when relationships between subjects (actors) are influenced by definitions of the situation, or when the reason for undertaking the research is to solve a problem which the actors have helped to define” [499 p. 600]. This research problem met elements of each of these criteria because it deals with groups of people within an organisation whose characteristics, ideas, strategies and behaviour are complex and difficult, if not impossible, to predict [500]. It follows that the (post-)positivist paradigm was not well suited to the research problem.

3.3 Research method

The relationship between research problem, objective and methods is an important one. Consideration of this relationship allows the researcher to come to an informed decision about the research design; to decide which method(s) are appropriate for a piece of research; and to anticipate the constraints and limitations that may impinge on any subsequent findings [490]. According to Myers [458], a research method is a strategy of enquiry that represents a way of finding empirical data about the world. Denzin and Lincoln [501] provide a comprehensive pedagogy for qualitative research that is consistent with this viewpoint. AR, for example, is regarded as a strategy of enquiry alongside others such as ethnography. Different techniques for data collection and approaches to analysis are available within this method, including the interview, direct observation, analysis of artefacts or documents and personal experience.

I have adopted this view of a research method throughout the thesis. In the following sections, AR, and more specifically PAR, is described as the research method. The rationale for selecting this method is provided. The focus of the chapter then turns to data collection and analysis techniques as part of the PAR process. The chapter concludes with a discussion of rigour in AR and the limitations of the AR method.

3.3.1 AR

AR aims to “solve current practical problems while expanding scientific knowledge” [458 p. 59]. As a general strategy for institutional change, AR has been practised since the 1920s [6]. Development of the AR method is often credited to Kurt Lewin [76, 77], a social and
experimental psychologist who combined theory, practice and change to study social psychology within the framework of field theory in the mid-1940s [78-80]. AR had a parallel but independent development which is attributed to the innovative work of psychiatrists, clinical and social psychologists and anthropologists at the Tavistock Group (later the Tavistock Institute) (see Trist and Murray [502]). The Tavistock Institute developed a method similar to Lewin in the 1950s and 1960s to study psychological and social disorders among soldiers who served in the Second World War [458]. Lewin later joined the Tavistock Institute and the two developments converged [78].

Lewin pioneered AR as a way of producing “knowledge about a social system while, at the same time, attempting to change it” [503 p. 121]. In his 1946 paper “Action Research and Minority Problems”, he proposed a spiral of steps, “each of which is composed of a circle of planning, action and fact-finding about the result of the action”. Baskerville and Wood-Harper [80 p. 92] observe that Lewin’s original model of AR included iteration of six phased stages: (1) analysis, (2) fact finding, (3) conceptualisation, (4) planning, (5) implementation of action, and (6) evaluation. Peters and Robinson [504 p. 115], in their paper on the origins and status of AR, present a synopsis of Lewin’s writings on the method. Amalgamating his two works on the subject of AR [77, 505] with those inferences from his more general theoretical writings on social psychology, they summarised the points Lewin made:

*The study of social groups and social problems can yield a set of general laws; and one can express these laws as “if/so” propositions and use them in conjunction with a diagnosis of specific situations to plan how to resolve or improve social conditions. One should, in turn, evaluate these strategies by observing their effects and modifying and re-evaluating the strategies if necessary.*

Although Lewin’s model has been much adapted, the essence of AR remains unchanged today. Myers [458], following Elden and Chisholm [503], claimed that a shared definition of AR has existed for the most part since Lewin’s seminal work. One of the most widely cited definitions of AR is Rapoport’s:

*Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework.*[75, p.499]

This definition emphasises the collaborative aspect of AR and dual contribution to practical problem solving and knowledge.
Although there is great diversity in contemporary AR methods, Elden and Chisholm [503] suggest a minimum of five elements that must be present for the research to be classified as AR. These are as follows:

1. **Purpose and value choice.** AR is used to solve the kinds of problems that yield general knowledge as well as practical solutions. AR researchers are not “value neutral”. AR is change oriented and researchers adopt the method to bring about change that has positive social value.

2. **Contextual focus.** AR is described as “context bound-inquiry” [499]. The contextual focus is on the content of the problem as well as its solution. The twin focus is necessary to solve “real-world” practical problems which are defined by the people who experience them.

3. **Change-based data and sense-making.** AR is change oriented, so the method requires data to track the after-effects of intended changes. AR requires researchers to interpret and make sense from data that are collected systematically over time.

4. **Participation in the research process.** AR requires those who experience or “own” the problem under study to be actively involved with the researcher and research process. As a minimum requirement, participants should be involved in selecting the problem and sanctioning the search for solutions. AR is a collaborative endeavour; active interaction is needed to encourage the ongoing cyclical and emergent nature of the process.

5. **Knowledge diffusion.** Classical AR assumes that a good solution to a chosen problem will spread by virtue of the value it adds to the existing stock of knowledge. Therefore, the results of the AR process must be written up according to the cannons of accepted social science practice. The researcher should identify the learnings that arose from the process and relate the topic to the existing literature to specify general knowledge.

Peters and Robinson [504 p.120] distinguish between weak and strong forms of AR. Both forms share three characteristics: being change-focused, organic and collaborative. The weak form is relegated to little more than a strategy for “getting things done”, whereas the strong form emphasises the central importance of the participants’ beliefs, values and intentions. In recognition of participants’ agency – that participants have created their own histories but are capable of changing or transforming reality – the strong form is emancipatory. That AR aims to produce “emancipation” is a defining characteristic of several well-known approaches to the AR method (see Kemmis and McTaggart [506] and Carr and Kemmis [507]).
Baskerville and Wood-Harper [80], in their paper on the diversity of AR methods in the IS field, offer an alternative, more pragmatic set of features. The authors define a boundary for IS AR that is characterised by multivariate social settings; interpretive assumptions about observation; intervention by the researcher in the problem setting; participatory observation; and the study of change in social systems. In their comparison of AR forms, the authors identify four types of characteristics that are conducive to comparative analysis. The authors distinguish between: iterative and linear (process); fluid or rigorous (structure) forms; collaborative, facilitative and expert styles of typical researcher involvement; and the primary goals of organisational development, systems design, individual learning and theory development.

It is worth pointing out that there exists disagreement about what constitutes AR in IS. Authors variously define models of AR that are more or less exclusive. This variation leads to confusion about the IS AR tradition [80]. Recognising that there is not one single, definitive AR method, Baskerville and Wood-Harper [80] appeal to the “vocational” nature of the discipline in their efforts to construct a more inclusive boundary for AR in IS. The authors contend that the lines between action and AR are not (or should not) be so easily drawn in our field. They call attention to the wider debate about inclusion and exclusion of certain IS practices as valid forms of AR. For example, consulting is widely considered to be a false claimant to the AR method. The inclusion of long-established, action-based IS, such as sociotechnical enquiry, is equally problematic because these approaches often do not explicitly claim to adopt the AR method [508].

It is apparent that AR defies easy description. The reader who reviews the literature in search of an all-encompassing definition, is instead rewarded with an appreciation of the diverse opinions about what is considered to be AR. Baskerville and Wood-Harper, for example, venture AR as something of a shining example of post-positivist research. “It is empirical, yet interpretive. It is experimental, yet multivariate. It is observational, yet interventionist” [79 p. 236]. Dick [509] describes the AR method as enigmatic. It is organic and emergent, but does not proceed without a plan. It requires the deliberate intervention and active self-involvement of the researcher, but seeks to uphold the principles and values of the problem owners. It is collaborative and inclusive, though the roles of researcher and participant, subject and co-researcher, and the extent to which each is involved in aspects of the process is highly variable. In the almost half century since the term AR was coined, much has changed in the world and the ways in which researchers study the world have changed in response. “It is likely that the ideas behind Lewin’s work remain viable today only because they are being
practiced in new ways, in innovative research designs, and applied to new problems” [503 p. 121].

3.3.2 PAR in context
PAR is one of several forms of AR that have emerged since the Lewinian definition and is the form of AR adopted in this thesis. According to Baskerville [78 p. 17], PAR is distinguished from earlier forms by increased client participation, such that “co-researcher status” is accorded to participants belonging to the client organisation [503]. The roles of researcher and participant are emergent, less distinct, and take on more collaborative and synergistic forms [78]. This observation is in keeping with Lewin’s proposition that “causal inferences about the behaviour of human beings are more likely to be valid and enactable when the human beings in question participate in building and testing them” [510 p. 86].

In PAR, client participants are “actively engaged in the quest for information and ideas to guide their future actions” [6 p. 20], and share in the responsibility for theorising [78]. To fulfil this responsibility, researchers and clients inform the research process in different ways; each comes with their own body of theoretical knowledge. According to Baskerville [78] and Elden and Chisholm [503], researchers draw on their knowledge of the AR method and general theories (in IS) while client participants introduce situated, practical knowledge into the research process. It follows that the social setting is realigned: “free to self-reorganize rather than be artificially determined by the external researchers” [78 p. 17]. By this token, PAR is founded on the assumption that reality is socially constructed [511] and social systems are self-referencing [512].

Whyte and colleagues’ work on PAR is noteworthy. The authors argue for the scientific and practical value of PAR. In one of their earliest works, they define PAR as an approach in which:

Some of the people in the organization or community under study participate actively with the professional researcher throughout the research process from the initial design to the final presentation of results and discussion of their action implications. [6, p.20]

They illustrate the PAR process with three case studies: one with Xerox Corporation in New York State, another with the FAGOR group of the Mondragon cooperatives in Spain (see Whyte, Greenwood and Lazes [513]), and Thorsrud’s work [514] in the Norwegian shipping industry (see Whyte [515]). A variety of treatments of the subject of PAR can also be found in Whyte [6].

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Later, Greenwood, Whyte and Harkavy [81] published on the subject of PAR, both as a social science research method and process, and the goal of such research. The authors described the key features of PAR (Table 14) and presented the West Philadelphia schools, Xerox Corporation and Mondragon cooperative cases to argue for the emergent nature of PAR and its inherent ability to link participation, social action and knowledge generation. Following this, Elden and Chisholm [503] presented Greenwood and colleagues’ paper among a collection of reports on novel variants on contemporary AR in their introduction to the special issue on AR in *Human Relations*. In this introduction they identify several refinements Greenwood and colleagues contributed in relation to the idea of participation in AR. First, AR is emergent; none of their three cases in [81] began as PAR. Hence, all AR should strive to be more participatory because enhanced participation is required to improve the scientific quality of the research results. Perhaps most significantly, Elden and Chisholm draw attention to the authors’ point that participant-managed research ought to be viewed as a matter of degree, not dogma. The nature of participation in AR is a product of the local situation and full participation in all phases of the research is seldom feasible.

In this thesis, therefore, I adopt the description of PAR given by Greenwood, Whyte and Harkavy. According to the authors, PAR is:

*a form of AR in which professional social researchers operate as full collaborators with members of organizations in studying and transforming those organizations. It is an on-going organizational learning process, a research approach that emphasizes co-learning, participation, and organizational transformation. [81 p. 177]*

This definition was chosen because it is prevalent in the business and management literature, it reflects the need for researchers to become deeply involved with the organisation, and, above all, it represents the working relationship between participants as a partnership. Now that this subsection has identified and defined PAR as the research method, and justified this choice, the subsections that follow move to address the structure of the PAR process as it emerged to address the research problem.
Table 14. Key features of PAR [81 p. 178 - 180]

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<th>Feature</th>
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<td>Collaboration</td>
<td>• Involves collaboration between members of the organisation being studied and a professional social researcher.</td>
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<tr>
<td></td>
<td>• Practitioners are involved in all aspects of the research process, from the initial design of the project through data gathering and analysis to final conclusions and actions arising out of the research.</td>
</tr>
<tr>
<td>Incorporation of local knowledge</td>
<td>• Members of organisations are seen as knowledgeable and intelligent. Incorporating this knowledge results in the development of individual’s own roles and stakes in the research process and outcomes.</td>
</tr>
<tr>
<td>Eclecticism and diversity</td>
<td>• Social reality is a complex, multi-causal web of forces that are historically dynamic. A multidisciplinary and eclectic approach is required to “model” this complexity.</td>
</tr>
<tr>
<td></td>
<td>• PAR is tailored to the situation at hand. It mobilises theories, methods, and information from whatever source the participants jointly believe to be relevant.</td>
</tr>
<tr>
<td>Case orientation</td>
<td>• Building theory and method in PAR is an intrinsically case-oriented activity. It attempts to learn general lessons from specific cases, to operationalise concepts, and the like, through repeated case applications.</td>
</tr>
<tr>
<td>Emergent process</td>
<td>• PAR as an emergent, intensifying process that is able to gain increased dimension and depth throughout the entire research process.</td>
</tr>
<tr>
<td>Linking scientific understanding to social action</td>
<td>• Participation in the research process is self-managed and pluralistic, reflecting participants’ own understandings of their social system.</td>
</tr>
<tr>
<td></td>
<td>• These understandings are conditioned by the organisation members’ rights and obligations to act within this system so the research produces results that are both socially and scientifically meaningful.</td>
</tr>
</tbody>
</table>

3.3.3 Iterations of the PAR cycle

Lewin and most subsequent researchers have conceived of AR as a cyclical two-stage process. According to Baskerville and Myers [471], following Blum [516], the basic structure comprises of two stages: first, a diagnostic stage which involves a collaborative analysis of the social situation by the researchers and participants; and second, a therapeutic stage involving collaborative change experiments. This structure has been elaborated in different representations of the same process (see, e.g., Kemmis and McTaggart [506], Elliot [517], McKay [518]), but the underlying cyclical approach to action and reflection is the same.

Susman and Evered [499] (Figure 16) elaborate on the generic two-stage model, suggesting that AR ought to be viewed as a cyclical process with five phases. These phases are: (1) diagnosing during which the identity and scope of the problem is determined; (2) action planning, where the steps necessary to address or alleviate the problem are recorded; (3) action taking, which implements the planned actions; (4) evaluating, where the planned actions are considered in light of the desired outcomes; and lastly 5) specifying learning, where the results of the AR process are distilled and recorded. These stages are regulated by the relation between the researcher and the research environment, termed the client-system infrastructure.
The approach to PAR for this thesis is similar to the general AR process described by Susman and Evered. The authors’ approach provided what Baskerville described as “additional structure” – that which is “often imposed upon AR projects to achieve scientific rigor” [519 p. 3]. More importantly, Susman and Evered’s approach has been successfully used for IS research in the past (see Baskerville [519] and Myers and Olesen [520]), and more recently, for PAR studies in the field of IS (see Street [521]).

Our general PAR process for this thesis can be described as follows (Figure 17). Three iterative cycles of PAR, each successively building upon the learnings reaped from earlier cycles, were undertaken. Each cycle was composed of five steps, namely diagnosing, action planning, action taking, evaluating and specifying learning.

In the first cycle, we developed a small BI prototype in keeping with the tenets of the Multiview2 ISD methodology to elicit information about perioperative outcomes. As a prototype, the goal was to provide anaesthetists with information about perioperative outcomes as early on in the project as possible. We recognised that the development was likely to require significant data discovery efforts, so we made the choice to focus on the assessment of data quality at the outset. If the quality could not be assured then any work to conceptualise the work of risk communication might be considered less meaningful. The first
PAR cycle manifested our limited knowledge of the methods anaesthetists use to assess and estimate the risks and benefits of surgery and to communicate this information to patients.

Figure 17. Approach to PAR for this thesis.

In the second cycle, we focused on the sociotechnical aspects of the ISD. We explored how the work of risk assessment and communication is achieved during preoperative anaesthetic assessment with a view to using this information to guide future development. Having constructed a conceptualisation of the work of risk communication, we turned our attention to what the data could tell us about perioperative mortality at our institution and how this might compare to the international literature.

In the third PAR cycle, we used quantitative methods to describe 30-day perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City
Hospital. This cycle was needed in order to make an assessment as to the value of this information for use in preoperative risk assessment and communication.

Throughout each cycle, we sought evidence to confirm whether our concepts were appropriate, and using reflection we conceptualised and generalised what happened (action). Multiple methods for data collection and data analysis were used to collect and analyse data within changing contexts and time periods as the PAR process iteratively progressed.

3.3.4 Rationale for adopting PAR as the strategy of enquiry

Having described the approach to PAR, it follows that the researcher should also outline their reasons for using the method. PAR researchers make a commitment to integrate three basic aspects of their work: participation (life in society and democracy), action (intervention informed by experience and history), and research (soundness in thought and the growth of knowledge) [522]. Brydon-Miller and colleagues [523], in defining PAR, describe the method as the sum of its individual terms. They recognise the multiple and varied combinations of these terms and their meanings, as well as the particular assumptions and processes that accompany them. Naturally, the rationale for classifying this thesis as PAR lies in the intention behind these terms.

The principle of participation extends the involvement of participants and is the key to distinguishing PAR from other research methods. The relationship between participant and researcher is best seen as a partnership in which there is co-management of the research process and co-generation of problem solutions [503]. Although the research process subscribes to the principle of partnership in the real sense of the word, PAR is emergent and the extent of client participation is a product of the local situation. Dr Doug Campbell and I were actively involved in the struggle to solve a practical problem. In the broadest sense, the problem was situated at the intersection of two practical domains of knowledge. These were: (1) anaesthesia and (2) IS. In agreement with Whyte [515], the research literature and expertise in any single discipline would not have provided an adequate base for solving the problem. Instead, we needed to integrate information and ideas between disciplines and to capitalise on local knowledge. We were best able to do this if each individual contributed as an active participant in the research enterprise. By working in partnership with one another throughout the project, our approach was participatory.

The principle of action in AR has been typified as a way of creating knowledge within the context of practice itself [524]. Action is necessarily interwoven into the research process because solving a practical problem is a primary goal of the work. Chevalier and Buckles
[522 p. 6] draw on pragmatist thinking in their emphasis on “the need for research activities and techniques that actually ‘work for people,’ the kind that has meaning in real settings”. We used PAR because we believed that real-world action must be taken in order to solve the practical problem. The disciplines of anaesthesia and IS are both, to varying degrees, applied, procedural and vocational in nature. It follows that our approach to problem solving would naturally reflect these characteristics. We used PAR because it gave us licence to apply our diverse skillsets to the practice problem. The ability to mobilise this expertise far outweighed the potential disadvantages of researcher bias through personal involvement in the ISD process. Research methods that are subject to the constraint of non-intervention [525] are ill-suited to the study of practical problems that require the researcher to bring about change to solve them [79]. This is because change necessitates intervention.

The last principle views research as a social process of gathering knowledge. AR seeks to achieve both practical and research objectives by linking theory and practice, and thinking and doing [526]. Consistent with Street and Meister [521], Dr Campbell and I could not see any reason why it would not be possible to make a dual contribution to practice and scientific knowledge through our efforts to solve a practical problem. This belief could be attributed to the character of the research environment. In addition to the provision of clinical care, Auckland City Hospital also has a strong research focus. Our investigation was conducted in DAPM. As a clinical research analyst within DAR (located within DAPM) and a PhD student, my practice was also my research, or at the very least my practice facilitated other anaesthetists’ research. The practice of clinical research has an obvious role in guiding the provision of patient care so the same could be said for Dr Campbell, as both a consultant anaesthetist and active, clinician researcher within the respective departments. PAR is a process that helps to sustain organisational learning [454] because AR is professional development [527-529]. For Dr Campbell and I, the use of PAR was a good fit for the research problem because its use required no significant departure from our natural way of working.

3.3.5 PAR and competing approaches
At this point it is useful to distinguish PAR from other competing approaches. This research bears resemblance to collaborative practice research (CPR), action design research (ADR) and action case among others. While I acknowledge this resemblance, I do not seek to classify this thesis as having used either of these alternative methods of research. This position is outlined in the paragraphs that follow.
ADR [530] reflects the premise that artefacts are ensembles shaped by the social setting through development and use. The method conceptualises the research process as “containing the inseparable and inherently interwoven activities of building the IT artefact, intervening in the organization and evaluating it concurrently” [530 p. 1]. The emergent nature of our research process and my commitment to addressing the different facets of the practical problem as they manifested with each AR cycle meant that the focus did not include the narrow domain of product design and we did not seek to elicit design principles.

This research approach also has much in common with CPR. The CPR approach (see Mathiassen and colleagues [531, 532]) seeks to establish fruitful collaboration between researchers and practitioners. It exemplifies pragmatist thinking through the application of pluralist research methods and is proposed as a way to organise and conduct research into systems development practice. In classifying this research as PAR, I distinguish collaboration as a lesser form of participation. Dr Campbell and I worked in partnership as co-researchers, with each of us having a stake in the “truth”; and at the conclusion of the first PAR cycle he agreed to co-supervise this thesis. To the extent that each of us was actively involved in all stages of the research process in one way or another, collaboration did not appear to do the working relationship justice.

Lastly, I address the action case method which seeks to balance intervention and interpretation in IS research studies (see Vidgen and Braa [493] and Braa and Vidgen [492]). This approach combines AR and the case study to “assist IS researchers in navigating the space of in-context research” [493 p. 524]. Examination of our approach reveals many similarities with the action case method. Semistructured interviews formed the primary data source in the second PAR cycle and an interpretive frame for data collection and analysis was adopted throughout this cycle. To distinguish our approach from action case, I revisit the central idea of participation in PAR, the degree of which exceeds that described as characteristic of action case. I would also reflect on the motivation for conducting the interviews. The interviews provided deep insight into the practice of risk communication. They were not planned as sources of data for pre- or post-mini-case studies to elicit the effects of ISD [493]. Rather, they were conducted in the spirit of the emergent change process, motivated by the learnings that arose in the first PAR cycle and intended to inform the next.

3.4 PAR and the Multiview methodology

Having described the overarching PAR process and identified the development of a BI prototype as a key part of this process, it is fitting to describe the framework for the ISD. The
Multiview methodology [4] is used as a diagnostic (and sensitising device) to inquire into the characteristics of BI development. It provides a general schema, a way of interpreting and codifying the richness of the problem area and problem-solving process as well as a way of seeing those aspects of BI development that do not fall within its gamut. In this way, the framework is used to investigate the appropriateness of Multiview – a pre-Internet systems analysis and design methodology [533] – to inform the development of a BI prototype in the healthcare sector. To this end, the following subsections are organised as follows. First, an overview of the Multiview1 methodology is provided; second, the Multiview2 methodology is described; and third, the rationale for using Multiview2 in the context of PAR is provided.

3.4.1 The Multiview1 framework
Multiview originated in response to traditional ISD methods that had strong ties to the field of engineering and were deeply rooted in technical rationality. As an approach to ISD, Multiview has been in a continual state of development since its inception [534]. Multiview was first described in 1985, though its foundations were originally laid several years earlier [535, 536]. Faced with teaching systems analysis to students at the Thames Polytechnic in 1974, Avison and Wood-Harper found that existing descriptions of the development process imparted too narrow a view of ISD [537]. The authors regarded available methodologies as being overly formal, prescriptive and almost “scientific”. The descriptions used in the course material did not coincide with their experience developing IS in practice. Multiview was formulated to address these deficiencies. The approach was developed to take into account the human and organisational, social and contextual aspects of ISD at a time when alternative approaches emphasised the technical aspects of development [534, 537], being either data-oriented [538, 539], process-oriented [540] or both [541, 542]. Further, Multiview was intended to represent the process of ISD as both iterative and contingent rather than rigid and prescriptive [537].

Until the late 1990s, Multiview1 was the most widely used definition of the framework [4]. In its original form, Multiview described an approach to the analysis and design activities deemed necessary to alleviate information processing problems. This approach was intended to facilitate communication between project stakeholders about what was needed and what was proposed. Multiview1 acknowledged the different backgrounds and viewpoints held by groups and individual stakeholders. In doing so, the framework was intended to help provide answers to the following questions [4 p. 10]:

1. How is the information system supposed to further the aims of the organisation using it?
2. How can it be fitted into the working lives of the people in the organisation who are going to use it?

3. How can the individuals concerned best relate to the computer in terms of operating it and using the output from it?

4. What information processing function is the system to perform?

5. What is the technical specification of a system that will come close enough to doing the things you have written down in the answers to the other four questions?

In its original form, Multiview was comprised of five stages that corresponded to each of the above questions. These stages were: (1) analysis of human activity, (2) analysis of information (sometimes called information modelling), (3) analysis and design of sociotechnical aspects, (4) design of the human-computer interface, and (5) design of technical aspects. Each of these five “views” was considered requisite for the development of a complete IS; one that gave due consideration to both the human and technical aspects of development [543].

Avison and Wood-Harper offered two representations of Multiview in their account of its early definition [4]. One representation of the methodology is shown in Figure 18. Working from the outside in, the five stages of Multiview are seen to progress from “the general to the specific, from the conceptual to hard fact, and from issue to task” [4 p. 34]. A more detailed overview of the stages of the Multiview methodology and the relationships between them is shown in Figure 19. To preserve authenticity, the boxes refer to the analysis stages, the circles to the design stages, and the arrows to the interrelationships between them. Outputs from each stage either become inputs to subsequent stages or are major outputs of the methodology. These outputs are shown as dotted arrows in Figure 19, alongside the information that they provide and the questions that they are intended to answer.
Each of the stages in Multiview corresponds to “five different views, all of which can be emphasised, reduced in scale, or even omitted, according to (or contingent on) the circumstances” [4 p. 34]. Each of the five stages in Multiview is supported by tools and techniques which are applied as and when needed. These tools and techniques are fully described later in the thesis alongside detailed descriptions of the stages of the Multiview framework. The resultant approach to ISD is a function of the level of expertise of the user and analyst and the nature of the particular situation and complexity of the problem. That is to say, the approach to ISD is a function of the triad between the analyst, the methodology and the situation.

**Figure 18.** The Multiview methodology [4, p.25].
3.4.2 The Multiview2 framework

Multiview was superseded by Multiview2 in the late 1990s. The new version reflected recent contributions in the IS literature and lessons learnt from 10 years of its use in practice [537]. In its original form, Multiview omitted the software construction, implementation and maintenance activities of the systems development life cycle, implying that these ought to be dealt with outside of the methodology. Excluding these activities from the methodology appeared to infer a waterfall approach to ISD. Although Multiview1 posited a three-way relationship between the analyst, the methodology and the situation, the framework also overlooked the issue of how any given instantiation of the triad might come about in real-world practice [534]. To address these shortcomings, Avison and Wood-Harper adopted a broader scope for Multiview2 by including the activities of software development, implementation and production operation. The authors described the evolution of Multiview into Multiview2 in a paper in Information, Technology and People in 1998. The new framework was intended to offer a rich implementation of the multiple perspective approach related to unbounded systems thinking [544]. The authors described how the original themes of organisation, work, and technical artefacts were preserved in Multiview2, but with “a more
satisfying sense of closure insofar as the endeavour of building, implementing, and maintain
an information systems goes full-circle” [534 p. 130].

Multiview2 attempts to reconcile ideas from several systems development approaches,
especially soft systems methodology (SSM), sociotechnical design, structured analysis, and
information modelling [545]. Vidgen [533] observed that Multiview2 (see Figures 20 and 21)
is structured in three tiers: general framework, local methodology and methods/techniques. As
a framework for ISD, Multiview2 is intended to inform the emergence of a local, situation-
specific ISD methodology, which results from the engagement of the business or systems
analyst with the problem situation. Within the bounds of the methodology, a range of methods
and techniques such as requirements engineering, ethnographic studies or human-computer
interface design are applied by the change agents to improve a problem situation. Following
Oliga [546], Avison and Wood-Harper distinguish between the terms “method” and
“methodology” on the grounds of the level of abstraction. The authors contend that “a method
is a concrete procedure for getting something done while a methodology is a higher-level
construct which provides a rationale for choosing between different methods” [537 p. 12-14].

Change agents draw on the interpretive scheme (Figures 20 and 21) in their struggle to
develop and deploy information systems (action) in an organisational context (structure).
Avison and Wood-Harper take inspiration from Giddens’ [547] structuration theory for their
interpretive scheme, suggesting that ISD is constrained by the organisational context in which
it is developed and deployed but, at the same time, capable of changing that context [534].
The interpretive scheme of the Multiview2 methodology comprises four components:
organisational analysis, information system modelling, sociotechnical analysis, and software
development.
These aspects are described briefly as follows:

- **Organisational analysis** is focused on understanding the organisational requirement for an IS. This activity is described by Vidgen [548]. It involves gaining an appreciation of the purposeful activity that the IS is intended to support [534].

- **Information system modelling** is concerned with the development of a technical representation of the IS. Object-oriented analysis [549, 550] and business process modelling techniques such as role activity diagrams [551] are used in preference to traditional analysis methods such as data flow diagrams and entity-relationship models.

- **Sociotechnical analysis** draws from ETHICS [543], ethnography [552, 553], the Scandinavian School of participatory design [554], as well as a general interest in how work is accomplished in actuality [555]. Activities in this quadrant explore ways of handling the whole question of introducing an information system into people’s work, which are laden with assumptions about how people go about their work and more generally, how organisations function [4, 555].

- **Software development** encompasses the design and construction of software, hardware, and communications technologies. By convention, it extends to both the
internal design of the software comprising of methods, functions and classes [556, 557], and the external design of the human-computer interface [558].

![Diagram of Multiview2 framework](image)

**Figure 21.** The Multiview2 framework [534].

Multiview2 supports a contingent and holistic approach to ISD. Tools and techniques are omitted or adapted and applied according to the problem situation, type of project and skillset of those individuals (change agents) involved in the ISD process. Change agents view the problem situation from multiple perspectives in an approach related to unbounded systems thinking [544]. Complex problem solving, such as that observed in ISD, requires the application of knowledge from multiple disciplines and professions, each employing different paradigms of thought. The three perspectives identified are: (1) technical perspective (T); (2) organisational (or societal) perspective (O); (3) personal (or individual) perspective (P) [559].

The requirement to exercise these perspectives is manifest by their alignment with the Multiview2 stages of technical design and construction (T), sociotechnical analysis and design (P), and organisational analysis (O). Multiview2 also highlights the need for ongoing mediation between the technological, organisational and personal aspects of IS development projects [534]. These aspects are accounted for across four dimensions: social (a concern with...
the organisation and individuals) and technical (a concern with the “objective”), and analysis (a focus on “what” is required) and design (a focus on “how” these requirements will be achieved) [533]. Each dimension must be considered if the ISD is to generate a robust technical artefact to support purposeful organisational activity [534]. However, Avison and Wood-Harper suggest that the mix of these aspects will vary from one project to the next, in keeping with the contingent nature of the local methodology. A summary of the characteristics of the framework is presented in Table 15.
Table 15. Characteristic features underlying Multiview2. Adapted from [534, 537].

<table>
<thead>
<tr>
<th></th>
<th>Aims</th>
<th>Guiding principles</th>
<th>Non-functional constructs</th>
<th>Functional constructs</th>
<th>Influences</th>
</tr>
</thead>
<tbody>
<tr>
<td>To facilitate development of an information system that is complete in both technical and human terms</td>
<td>• Inseparability of object and subject worlds resulting in the symmetrical treatment of social and technical aspects of ISD</td>
<td>• Contingency and flexibility govern the choice of and use of tools and techniques within the Multiview framework</td>
<td>• Mediation: The essence of the ISD through which objectivist accounts of meeting real-world requirements and subjectivist accounts of a socially-constructed reality achieve a synchronisation [548]</td>
<td>• Organisational analysis: Studies the organisation – its main purpose and problem themes - to understand the organisational requirement for an IS and gain an appreciation of the activity that the system is intended to support.</td>
<td>• SSM (mode 1) [560], employing the techniques of rich picture building, CATWOE definition and the creation of root definitions, and conceptual models</td>
</tr>
<tr>
<td></td>
<td>• Learning approach to ISD requiring the analyst to reflexively monitor unfolding events.</td>
<td>• Contingency and flexibility govern the choice of and use of tools and techniques within the Multiview framework</td>
<td>• Multiple perspectives – technical (T); organisational or societal (O); personal (or individual) – are needed to inform the particular instance of Multiview2</td>
<td>• Analyst-methodology-problem situation triad. The Multiview2 methodology provides a basis for constructing a situation-specific method, which arises from a genuine engagement of the analyst with the problem situation.</td>
<td>• Radical change and business process redesign [563]. IT is seen as a business enabler and change is in business environments</td>
</tr>
<tr>
<td></td>
<td>• Information modelling: The purpose of this activity is to develop a technical representation of the proposed IS</td>
<td>• Learning approach to ISD requiring the analyst to reflexively monitor unfolding events.</td>
<td>• Information modelling: The purpose of this activity is to develop a technical representation of the proposed IS</td>
<td>• Sociotechnical analysis: Activities in this quadrant seek to produce a “good fit” design, which takes into account the needs and working environment of people in the organisation on the one hand, and the organisational structure, computer systems and work requirements on the other hand.</td>
<td>• Ethical analysis to acknowledge stakeholder’s multiplicity of moral ideas [565]</td>
</tr>
<tr>
<td></td>
<td>• Software development: Encompasses the internal and external design and construction of software, hardware and communications technologies.</td>
<td>• Learning approach to ISD requiring the analyst to reflexively monitor unfolding events.</td>
<td>• Software development: Encompasses the internal and external design and construction of software, hardware and communications technologies.</td>
<td>• Software development: Encompasses the internal and external design and construction of software, hardware and communications technologies.</td>
<td>• Technology foresight and future analysis to think about the impact of the intervention on stakeholders and elicit a potential role for technology [552, 556]</td>
</tr>
</tbody>
</table>

93
3.4.3 Rationale for adopting Multiview2 in the context of PAR

Multiview2 was adopted as the framework for development of the BI prototype and this subsection explains the reasons for its adoption. Just as it is important to align the research problem, method and paradigm, it is equally important to relate the problem context to the problem-solving ISD methodology (see McKay [518]). The development of new ICTs in healthcare is a complex and dynamic sociotechnical process [496]. Throughout much of this process information is scarce, contradictory or asymmetrical and it can be difficult to make sense of it to apply it in practice [534, 569]. The healthcare environment, in particular, is often characterised by “missing information, shifting goals and a great deal of uncertainty” [570, p.142] and ambiguity. This makes traditional approaches to systems development difficult to successfully apply in this context [570]. Successful creation of IT in healthcare requires a flexible, iterative and incremental approach to development; one that gives due emphasis to the need for continuous learning, experimentation and improvisation [496]. Proof-of-concepts, prototypes and pilot projects are commonly used as part of healthcare ISD projects to learn more about the problem and its possible solutions [571]. The features of Multiview2, namely its support for development that is contingent, even-handed and situated see the approach well-suited to early development efforts such as proof-of-concept, prototypes and pilot projects in healthcare.

Combining Multiview2 and PAR for this research is equally appropriate. Multiview was developed in the tradition of AR, where there is a close interaction between theory and practice and between researcher and participant [4]. The use of Multiview in real-world situations through AR has provided many lessons about the practice of ISD [537]. Multiview has been revised on numerous occasions to reflect these lessons learned [4]. A secondary effect of the interest in Multiview has been the increasing uptake of AR by the IS research community. AR combines theory with practice (and researchers with practitioners) in an attempt to solve an immediate problematic situation. Change and deliberate intervention are quintessential elements of the reflexive learning process. Avison and Wood-Harper represent Multiview as an “exploration” in ISD, and suggest that AR investigation provides an opportunity to see the framework in operation [537]. For the purposes of this research, and in keeping with Avison and Wood-Harper [534], we consider the development of an IS to be a problem-solving act, guided by the principles of AR through which Multiview is interpreted.

It is appropriate to reflect on the choice of ISD methodology in light of other, competing approaches. The problem of selecting among alternative methodologies for AR investigations is addressed by Jackson and Keys [572]. The authors developed a classification of problem
contexts along two dimensions: (1) the degree of complexity of the systems in which the problem is located, and (2) the nature of the relationships between the participants in the situation. Problem contexts can be situated in one of four categories: mechanical-unitary, systemic-unitary, mechanical-pluralist and systemic-pluralist (Table 16).

**Table 16.** Classification of problem contexts and alignment with problem-solving methodologies. Adapted from Jackson and Keys [572] and Mansell [573].

<table>
<thead>
<tr>
<th></th>
<th>Unitary</th>
<th></th>
<th>Pluralist</th>
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<tbody>
<tr>
<td></td>
<td>Decision-makers agree on a common set of goals and make decisions in accordance with those goals.</td>
<td>Problem solver can establish without too much difficulty the objectives of the system in which the problem resides.</td>
<td>Decision-makers cannot agree on a common set of goals and make decisions which are in accordance with differing objectives.</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
<td></td>
<td><strong>Mechanical</strong></td>
</tr>
<tr>
<td>Simple</td>
<td></td>
<td></td>
<td>Component parts of mechanical systems are passive, not purposeful and pluralism concerns differences amongst decision makers (possibly including the problem solver) outside the system.</td>
</tr>
<tr>
<td>systems</td>
<td></td>
<td></td>
<td><strong>Mechanical</strong></td>
</tr>
<tr>
<td>manifesting</td>
<td></td>
<td></td>
<td>Techniques of classical OR [574].</td>
</tr>
<tr>
<td>relatively</td>
<td></td>
<td></td>
<td><strong>Pluralist</strong></td>
</tr>
<tr>
<td>easy</td>
<td></td>
<td></td>
<td>Realist philosophy and positivist paradigm.</td>
</tr>
<tr>
<td>problems</td>
<td></td>
<td></td>
<td><strong>Systemic</strong></td>
</tr>
<tr>
<td><strong>Systemic</strong></td>
<td></td>
<td></td>
<td>Systems with many elements in close interrelationship that exhibit behaviour which is difficult to predict.</td>
</tr>
<tr>
<td>Complex</td>
<td></td>
<td></td>
<td><strong>Systemic</strong></td>
</tr>
<tr>
<td>systems</td>
<td></td>
<td></td>
<td>Socio-technical systems [526] or Viable Systems Diagnosis [575].</td>
</tr>
<tr>
<td>manifesting</td>
<td></td>
<td></td>
<td><strong>Systemic</strong></td>
</tr>
<tr>
<td>difficult</td>
<td></td>
<td></td>
<td>Dualist thinking or realist and structuralist respectively.</td>
</tr>
<tr>
<td>problems</td>
<td></td>
<td></td>
<td><strong>Systemic</strong></td>
</tr>
</tbody>
</table>

Drawing on this classification, Mansell [573], after Jackson and Keys [572], provided a rationale for selecting among four prominent methodologies for AR in ISD: operational research, SSM, sociotechnical systems design, and viable systems diagnosis.

The problem context for this thesis is considered to be systemic-unitary. Although the potential for pluralist decision-makers in future development cycles also emerged, Dr Campbell and I were in agreement as to the common goals of the project and decisions were made in accordance with these goals. The system, however, was partially observable, probabilistic, open, comprised of purposeful parts, and was undoubtedly subject to behavioural influences [572]. The system was also not straightforward to analyse and it was not possible to establish the likely effect of solutions to the problem without putting them into practice. The potential for plural decision-makers emerged in the second PAR cycle through consideration of anaesthetists’ practices for risk disclosure. “Hard” approaches to ISD, such as structured systems analysis and design method (SSADM) [577], were dismissed as inappropriate. Sociotechnical approaches to ISD are considered valuable in the case of
systemic-unitary contexts [572]. Multiview2 incorporates sociotechnical thinking and elements of SSM and therefore was an appropriate choice among competing methodologies.

Having reviewed the literature on the Multiview and Multiview2 frameworks and outlining the rationale for adopting Multiview2 in the context of PAR, the data collection techniques used throughout the PAR process are described in the next section before the data analysis techniques are reviewed.

### 3.5 Data collection techniques

We have seen that the PAR process, which was used as the strategy of enquiry in this research, reflects the interplay between the interpretive and pragmatic worldviews. It is only fitting that the data collection throughout the PAR process should too. Data collection methods focus on actions and changes that are intended to yield useful knowledge and on understanding socially constructed cognition through interpretation to yield interesting knowledge [474].

All AR generates data in the form of action and the meanings actors impose on action. Jonsson [578] provides a valuable introduction to the process of data collection in AR. According to the author, (interpretive) AR involves “using talk as data, i.e. as a medium towards the logic of action – talk as action as well as talk-as-report” [578 p. 374]. In their observations of the learning process, researchers generate “texts” to be interpreted. The interpretive action researcher is likely to tell stories. This is an obvious part of the ontological basis for interpretive research because social reality can only be interpreted (see Klein and Myers [460]). To provide a construction of reality that is credible [579] requires the collection of multiple sources of information and multiple measures of performance. Jonsson adds that the requirement for multiple data sources necessarily reflects the nature of social processes in the natural environment; that is, they cannot be constrained to the location where the researcher happens to be. People chat and solve problems in the most “unsuitable” places, so multiple and varied sources of data are necessary to complement the field notes of the researcher.

Many of Jonsson’s assertions apply equally well to the pragmatic scientific orientation of AR. The pragmatic action researcher is also a storyteller, but the purpose of the story is different. The pragmatist is not content to tell stories that are interesting [458, 474], rather the meaningfulness of the pragmatist’s story consists of its “making sense” practically [580]. Pragmatists are concerned with what works and how and why it works, but they are equally concerned with the inverse – what does not work and how and why this does not work [473].
At the forefront of the pragmatist’s approach is the assumption that practical relevance and usefulness are best understood through dialogue with all stakeholders [488].

Multiple methods were used to collect data in this project within changing contexts and time periods as the PAR process iteratively progressed. Using Myers’ [458] classification of data collection techniques, three broad sources of data were utilised throughout this project. These were interviews, field notes and documents. The use of these techniques throughout each PAR cycle is described in the following subsections and summarised in Table 17.

Table 17. Summary of data collection techniques used for each PAR cycle.

<table>
<thead>
<tr>
<th>PAR cycle</th>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
</table>
| PAR cycle 1 | • Field notes  
• Documents: pictures and diagrams; the hospital intranet site; software applications and code; email correspondence; presentation slides | • RCD in HISs |
| PAR cycle 2 | • Field notes  
• Transcriptions of semistructured interviews  
• Documents: email correspondence | |
| PAR cycle 3 | • Documents: email correspondence and comments and corrections on draft manuscripts | • RCD in HISs |

3.5.1 Data collection in PAR cycle 1

Data collection throughout this cycle reflected a pragmatic orientation to ISD. The pragmatist approach assumes that practical relevance and usefulness of theory and action is a view developed in dialogue with participants [581]. Accordingly, data collection techniques emphasise the situated awareness that Dr Campbell and I had. Reflection was the stuff of experience and ideas, which we related to action, practice and situations, and interaction and communication with other people were seen as central [581]. Indeed, as Dewey says: “enlightenment comes from the give and take, from the exchange of experiences and ideas” [582 p. 36].

Document analysis was the principle data collection technique used in this cycle. Myers defines a document as “anything that can be stored in a digital file on a computer . . . this does not mean that it has to be stored there . . . but in principle it can be” [458 p. 152]. Documents included pictures and diagrams that Dr Campbell, the external software developer and/or I drew, the hospital intranet site, software applications such as the anaesthesia information management system (AIMS), perioperative information system (PIMS) and patient administration system (PAS), computer code including stored procedures, email correspondence and presentation slides. As the software developed, I kept each successive iteration of the prototype to provide the basis for an analysis of its evolution (see [583]).
Email correspondence frequently consisted of dialogue between Dr Campbell and myself to record software development decisions and track change requests, issues, bugs and fixes. This was similar to Lincoln and Guba’s methodological log [579 p. 327]. I also used emails as “placeholders”. Since I was working and studying, a large amount of development occurred after hours so I would send emails to myself as a reminder of where I got up to that evening. These helped to facilitate the next day’s development activities.

Participatory observation was also used as a data collection technique in this cycle. I constructed field notes from my personal observations and reflections about what was happening at a particular time throughout the ISD process. Their content is aptly described by Payne and Payne [584 p. 168-169]: “feelings, initial impressions, half ideas, possible leads, even admissions of tactical errors”. To this list, I would add “planned next-steps”. Sometimes I would use I-mails [585] to record the field notes; at other times I would scribble down information about the people, place, time and goings-on.

To some extent, participant observation was unavoidable. As an employee, I was continuously exposed to the social situation of the research project and already had a well-established working relationship with Dr Campbell and with many other individuals who would come to influence the research process. My thoughts and feelings about the goings-on in the social environment in my role as an employee coloured my work as a researcher. I did not consider it possible for these streams of thought to come undone so I made no attempt to separate them.

RCD from the PIMS, PAS and AIMS were used in this cycle to feed the BI prototype, but the nature of these data sources is detailed in the findings chapter (Chapter 4) as a key part of the learning process.

### 3.5.2 Data collection in PAR cycle 2

The principal data collection technique employed in the second cycle was the qualitative interview. In agreement with Dr Campbell, I conducted multiple qualitative interviews with specialist anaesthetists in DAPM. The purpose of these interviews was to develop an understanding of the “work” of risk communication and how anaesthetists conduct this work in actuality [555]. The decision to pursue this line of enquiry emerged from a review of the data in the first PAR cycle, reflecting the emergent character of AR.

The rationale for conducting qualitative interviews is found in Myers [458]. In his text on qualitative research in business and management, Myers likened interviews to night goggles that permit the researcher to “see that which is not ordinarily on view and examine that which
is looked at but seldom seen” [586p. iv]. Few (if any) individuals are privy to the conversations between doctors and patients that occur prior to surgery. Qualitative interviews would seem to be an appropriate technique to describe the process and phenomenon of risk assessment and communication with the intention of understanding connections and wholes [578].

Myers [458] suggests that the choice of a particular data collection technique is also likely to be influenced by the extent to which the researcher is proficient with a particular technique. I had previously conducted semistructured interviews with eight Chief Executive Officers and one General Manager across nine non-government organisations in the health and disability sector on the subject of knowledge management [587, 588]; I was therefore familiar with the premises of the qualitative interview. As a common data collection technique in AR [589], I was eager to practise the craft.

I conducted semistructured interviews with specialist anaesthetists following the dramaturgical approach described by Myers and Newman [589]. The semistructured approach was chosen to obtain a balance between the rigidity imposed by a wholly structured instrument on the one hand, and the inability to achieve consistency across of unstructured interviews on the other. Semistructured interviews effectively position the researcher to pursue alternative lines of enquiry that may arise. Concepts derived from a literature review on informed consent and risk assessment and communication were used to inform the design of the interview instrument. This is consistent with Dick’s [509] assertion that relevant literature is defined by the process of data collection and interpretation. The relevant literature is not predetermined, but is instead driven by the emergent research themes. Democratic dialogue between Dr Campbell and myself refined the instrument to ensure that the relevant areas were canvassed. Briefly, anaesthetists were asked to provide their views on informed consent, describe their approach to risk assessment and communication at AAC, and to identify the challenges or other factors that modify their approach to risk assessment and communication.

Interviews were sought with specialist anaesthetists who were rostered to AAC at least once in the 6-month period prior to conducting the interviews. These anaesthetists are referred to as “clinic anaesthetists” from here on in. I used the departmental archive of weekly rosters for the operating rooms at Auckland City Hospital to determine which anaesthetists fulfilled this criterion. As a clinic anaesthetist, Dr Campbell arranged for me to seek interviews with our colleagues. The following excerpt is from the email sent from one of our team administrators on Dr Campbell’s behalf to prime anaesthetists for my requests for an interview.
-----Original Message-----
From: Doug (ADHB)
Sent: Monday, 28 May 2012 9:31 a.m.
To: DN (ADHB)
Cc: Michelle Soakell-Ho (ADHB)
Subject: RE: Next clinic meeting 12 June from 16.30

Dear DN

Can this email be circulated to all clinic specialist anaesthetists please

Doug

Dear All

Michelle Soakell-Ho is embarking on her PhD which will be investigating the use of IT in the area of preop risk assessment. Part of this will involve a series of structured interviews with clinic anaesthetists that should take 30-45mins and at a time convenient to you. Your consent is required ... I will tell you more at the meeting.

Some of the interviews might happen before this but I will talk to you individually if this is to be the case.

Regards

Doug

Following this, Dr Campbell arranged for me to interview the first three anaesthetists. I negotiated access for the remainder of the interviews and booked meeting rooms for each of the encounters either on site within DAPM at Auckland City Hospital or at AAC in the Greenlane Clinical Centre.

A total of 30 interviews were conducted with 29 different clinic anaesthetists between May 2012 and September 2012. At this point no new categories or themes emerged; data saturation had been reached and data collection was considered complete [590]. Three anaesthetists declined to participate due to time constraints. One anaesthetist was interviewed twice due to a staff shortage that required him to return to clinical duties and prematurely end the interview. All interviewees were emailed the participant information sheet in advance of the interview and written consent was obtained at the time of the interview. Interviews with participants lasted from 30 minutes to 60 minutes, excepting two that were longer than 60 minutes. Twenty-eight interviews were audio-taped; one interviewee requested that the interview was not audio-taped and this request was honoured. Immediately following that interview, I reconstructed the salient points from memory and typed these into a Word document.
After each interview, I wrote brief field notes in the form of I-mails or reflective emails sent to myself [585]. These emails included my observations, reflections and general after-thoughts about the conduct of the “meaning-making” occasion [591] and the data gleaned through the process [463]. In reality, this meant that each interview was in itself a “mini PAR cycle” [592]. All interviews were transcribed verbatim by a professional transcriptionist who had previously transcribed interviews for my postgraduate honours dissertation. At the time of interview, participants were advised that they could edit or correct anything that they considered inappropriate in the transcribed scripts. Similarly, interviewees were advised that they could withdraw from having their transcript subjected to further analysis at any time during the research without providing a reason for doing so. No participant chose to amend or withdraw their transcript. However, two anaesthetists provided supplementary data in the form of email correspondence. The interview transcripts, field notes and documents in the form of email correspondence generated more than 300 pages of single-spaced text.

3.5.3 Data collection in PAR cycle 3
RCD from the PIMS, PAS and AIMS were used in this cycle and, as mentioned previously, the nature of these data sources is detailed in the findings chapter (Chapter 4) as a key part of the learning process. Documents including email correspondence and comments and corrections on draft manuscripts were used in a similar fashion to PAR cycle 1.

3.6 Data analysis techniques
Data analysis occurred in the evaluating and specifying learning phases of each PAR cycle. Techniques for data analysis were guided by what participants were trying to find out at the time and the data collection techniques that were mobilised to this end. A broad overview of the analysis approach is described in the following subsections.

3.6.1 Data analysis techniques in PAR cycle 1
Throughout the first PAR cycle, the goal of data analysis was to facilitate narrative theory development through our drive to enact an envisioned state. This approach is common in the AR literature (e.g. [583, 593]) and requires the research process to move from empirical observation to generalisable relationships [594]. Langley described this as the central challenge faced by qualitative researchers: “Moving from a shapeless data spaghetti toward some kind of theoretical understanding that maintains the richness, dynamism and complexity of the data, but that is understandable and potentially useful to others” [595 p. 694].

Langley’s comparison of “sense-making” strategies provides a valuable platform from which to describe the analysis methods used in this cycle (and indeed throughout this thesis).
Process data, such as that collected throughout this PAR cycle, comprise mostly of stories about what happened and who did what, and when, why or how [595]. This reflects the nature of AR as a method that is well-positioned to understand how things change over time and why they change in a particular way. For the interpretive action researcher, the story is the interpreted work communicated through writing [596 p. 1182]. Storytelling is also de rigueur for the pragmatist who is interested to learn of the usefulness of his interventions in practice.

Consistent with Langley, narrative and visual-mapping strategies were used as organising strategies to permit the identification of events, activities and choices as the basis of theory development. Narratives, being closer to the raw data than visual maps, preceded the development of visual maps. On a more abstract level, the analysis approach mobilised inductive and deductive approaches as readily as data emerged and inspiration guided. This is consistent with Orton’s [597] view that (informally) most research is a function of both inductive and deductive analyses in which researchers cycle back and forth between theory and data. Consistent with Langley, Orton and pragmatist thinking at large, I took ideas from the data and attached them to theoretical perspectives (method, data, findings, theory), while at other times I took concepts from different theoretical frames and adapted them to the data at hand (theory, method, data, findings).

My approach shares similarities with the analysis techniques used by other authors. Following Street and Meister [521], I used Susman and Evered’s model to guide and shape the theory development. Similar to Kawalek and Wood-Harper [598], the Multiview2 framework was used as diagnostic (and sensitising device) to enquire into the characteristics of BI development. The framework was interpreted as a set of overlapping and concurrent concerns strewn across “artificial” PAR cycles. Consistent with Kawalek and Wood-Harper [598 p. 15], the aim was not to use Multiview2 in a prescriptive way. Rather, it provided a general schema, a way of interpreting and codifying the richness of the problem area and problem-solving process as well as a way of seeing those aspects of BI development that do not fall within its gamut. Accordingly, I sought out those events, activities and choices that were inconsistent with the expectations put forward by the Multiview2 framework. This analytic approach is consistent with Chiasson and Dexter’s [583] work on how the IS prototyping method changed social practices within a sociotechnical system. Following Miles and Huberman [463], the authors extracted both critical and illustrative events from the case as I did. The result is both an epistemological essay on experiences, events, choices and activities to provide general lessons (similar to Chiasson and Davison [583] and Kawalek and Wood-
Harper [598]) and the proposed extension of Multiview2 for BI development in the same manner as Vidgen [533].

3.6.2 Data analysis techniques in PAR cycle 2
In the second PAR cycle, the interpretive perspective shifted to the foreground and the meaning of anaesthetists’ work practices became the centre of scientific explanation. Accordingly, data were analysed in keeping with an interpretive and idiographic viewpoint [78]. The interview transcripts were analysed with the help of nVivo version 9 software (QSR International, 2012). Braun and Clarke’s [599] approach to thematic analysis was employed. Their approach is theoretically flexible and has been widely used across the social, behavioural and applied sciences. In brief, their approach was used as follows. First, the interview transcripts were read and re-read before a list of similarities, differences and extremes within the data was drafted. At this point, initial semantic codes were produced from the data. In keeping with their approach, I used Boyatzis’ definition of a code: “the most basic segment, or element of the raw data or information that can be assessed in a meaningful way regarding the phenomenon” [600 p.63]. Working systematically through the datasets, all data items that could form the basis of repeated patterns were coded. All data were coded inclusively to minimise the loss of context. Codes were then be collated into initial, overarching themes. Patton’s [601] criteria – internal homogeneity and external heterogeneity – were applied to the initial set of themes to ensure cohesiveness and independence respectively. Movement backwards and forth between the phases of analysis occurred until finally the specifics of each theme were refined, including the name, definition and scope of each. Additional data in the form of field notes and documents permitted methodological and data triangulation throughout the analysis process.

3.6.3 Data analysis techniques in PAR cycle 3
Data analysis for the third PAR cycle was consistent with the procedures for a single-centre, retrospective cohort study using secondary patient data. The analysis methods are presented in Chapter 7.

3.7 Ethical considerations, limitations and rigour
Having described the strategy of enquiry and data collection and analysis techniques, it is appropriate to reflect on the ethical considerations inherent in the approach and the limitations of the strategy as a whole. The remainder of this chapter proceeds as follows. First, I describe the ethical considerations in the research. This is followed by an overview of the criticisms and limitations of the AR approach and the steps that were taken to address this critique. The
chapter concludes with an overview on rigour in AR and the practices and procedures I took to ensure a balance between rigour and relevance throughout the project.

### 3.7.1 Ethical considerations

AR is carried out in real-world situations. The research process involves open communication between the participants and researcher, so ethical considerations in the conduct of the researcher’s work are paramount [458]. Indeed, one of the hallmarks of good AR is the identification of ethical issues and evidence that these have been addressed satisfactorily [602]. Ethical issues typically relate to informed consent, confidentiality and anonymity in the research process.

Informed consent is an important ethical principle in AR [458]. Arguably, the issue carries more weight in PAR. “Because the term ‘researcher’ can refer to both the community participants involved and external persons with specialized training” [603 p.45], researcher and participant roles are indistinct in PAR, “making it unclear how obtaining informed consent should be carried out” [604 p. 2337]. Writing generally of fieldwork in qualitative research, Myers [458] suggests that it is unrealistic for researchers to expect that they will obtain informed consent from everyone they might meet. It is, however, necessary to obtain permission from the appropriate authority to conduct the research in the organisation. Myers [458] wrote, that interviewees should also be asked for their informed consent beforehand.

The requirement to obtain informed consent is addressed by the ethics and institutional approvals for the study. We applied for and were granted ethics approval from the Northern X New Zealand Health and Disability Ethics Committee (1 The Terrace, PO Box 5013, Wellington, NZ) in May 2012. At the same time, we applied for and received institutional approval from the Auckland DHB Research Review Committee. The ethics committee number is NTX/12/EXP/105/AM01 and the institutional approval number is A+5546. As part of this process, both applications were signed off by the Director of Anaesthesia and Operating Rooms. This authorised the conduct of the research within DAPM at Auckland City Hospital. I kept electronic copies of letters from both the ethics committee and the research office (on behalf of the Auckland DHB Research Review Committee) granting these approvals. The research office at Auckland DHB provided written confirmation that identifying the hospital and institution by name in the write-up for this research imposed no additional obligations. It was unnecessary to seek either ethical or institutional approval prior to May 2012. This was because the research undertaken before this date was consistent with the organisation’s policies on clinical audit and the findings were not presented outside of the department.
I identified with Myers’ assertion that the researcher is unable to obtain informed consent from everyone they come into contact with. This was evident in the early stages of the project in which conversations were unstructured and informal, and were sought with a number of individuals. To minimise the risk inherent in the disclosure of personal, sensitive or confidential information I took the following steps:

1. Anonymity of individual contributors was preserved and no individuals were made identifiable in reports, publications or this thesis.

2. Written permission to include excerpts from email correspondence in the months prior to seeking ethics and institutional approval was obtained from those whose excerpts are included in this thesis.

3. Individual consent was gained from anaesthetists who participated in the semistructured interviews. Interviewees were given the participant information sheet in advance of the interview and gave their written consent at the time of the interview. Participants were free to withdraw their consent for me to use their interview, but none did so.

4. An ongoing process of information exchange between Dr Campbell and myself that determined the terms and conditions of our joint efforts and, in the broadest sense, constituted informed consent [604]. Dr Campbell officially took on the role of co-supervisor for this thesis in February 2012.

3.7.2 Criticisms and limitations of AR

Baskerville and Wood-Harper [79] document several criticisms of the AR method. These include the inability to distinguish the method from consulting, lack of impartiality of the researcher, lack of rigour, and the context-bound nature of AR. Myers [458] describes the tension between “doing the action” and “doing the research” and identifies this as one of the main difficulties faced by AR practitioners. He suggests that researchers may be inclined to overstate the importance of the AR intervention and the subsequent contribution to scientific research. Controlling AR projects is also known to be difficult [605]. These criticisms are addressed in the following paragraphs.

Baskerville [78] acknowledges the considerable overlap between AR processes and organisational consulting practices. He describes five key differences between the two approaches according to the following headings: motivation, commitment, approach, foundation for recommendations, and essence of the organisational understanding. Using his
approach, this research is distinguished from consulting as follows: (1) the research was motivated by its scientific prospects – this is epitomised in the nature of the research problem, the writing of this thesis, and in the drafting of scientific publications; (2) the investigation was carried out in a research department so our outputs were naturally of value to the scientific community; (3) we worked in partnership throughout the investigation – an unbiased, outsider’s viewpoint was not sought; (4) the foundation for learning was practice and theory oriented; (5) organisational understanding was derived from intervention and refined throughout subsequent iterations of the AR process. Our iterative AR process is distinguished from the linear “engage-diagnosis-action-disengage” approach used by consultants. According to the latter approach, we would have disengaged after the first AR cycle in which the prototype was developed.

A common criticism of AR is the lack of impartiality of the researcher. Researcher involvement is inherent in the AR process so this source of bias is inevitable. The researcher cannot remain a detached observer if they are required to intervene within the sociotechnical system they seek to study [606]. Drawing on research on human cognition, Koch and colleagues [606] describe the potential for highly emotive events to distort the research findings. This potential arises because the researcher is necessarily involved in the knowledge creation process. AR practitioners will remember the highly emotive situations and events more vividly than those in which there is little emotion involved. It is not uncommon for the AR practitioner to encounter highly charged situations for two reasons. First, the AR practitioner is highly absorbed in the change process. Second, the nature of AR is to promote change and change evokes different emotions in different people.

Closely related to this criticism is the context-dependent nature of AR and the implications this holds for generalisability of research findings. According to Koch et al. [606], limited generality in AR is often attributed to its focus on in-depth study of a small number of sociotechnical systems (e.g. 1–3 organisations). AR studies are lengthy endeavours because the researcher must enact change and then study the consequences, and usually more than once. The time required to conduct quality AR projects precludes the study of large numbers of organisations. It transpires that AR produces narrow learning in context. This means that researchers must be restrained in their generalisations.

The spiral approach to AR, comprising of multiple cycles in which each cycle is informed by those that came before it, can minimise researcher bias and increase generality of the findings. Successive iterations broaden the scope of the research and allow the researcher to collect data about the same units of analysis in relatively independent settings. Koch and colleagues
draw on the methods adopted in their study on the introduction of groupware in a large civil engineering company to illustrate this. The authors considered the organisational department as a unit of analysis and so were able to widen the scope of the research (e.g. the areas of the client organisation involved in the research) by including additional departments within the same organisation. They argued that their findings had high external validity because they held true over multiple instances of this unit of analysis, even though only one organisation was studied. The authors likened this effect to that which occurs when researchers choose a wider sample population in quantitative studies.

Koch and colleagues contend that effective application of the cyclical and iterative approach to AR has the potential to increase rigour. Using their rationale, Dr Campbell and I broadened the research scope between the first and second PAR cycles. Although the prototype was developed by Dr Campbell and myself with mentorship from the external software developer, Dr Campbell and I also sought feedback through the evaluation phase from a wider group of anaesthetists. Dr Campbell presented the software artefact to DAPM at one of the weekly Clinical Forum Meetings. In the second PAR cycle, I interviewed a number of anaesthetists about their risk assessment and communication practices, the majority of whom were not affiliated with DAR. By broadening the involvement to include a wider group of anaesthetists, the findings should be more transferable.

Another criticism of AR is that it is difficult to do research that solves a practical problem while at the same time produces research findings worthy of publication [458]. In part, this is because the collaborative character of the approach diminishes the researcher’s ability to control the AR process and associated outcomes [78]. The high degree of personal involvement means that researchers run the risk of solving practical problems at the expense of rigorous contributions to knowledge [79]. Rapoport [75] saw this as the “goal dilemma” of AR and proposed several ways of safeguarding the scientific goals of the approach. One way is for the individual researcher to provide the extra time necessary – evenings and weekends – to bring the scientific side of the work up to a publishable standard. Alternatively, costs may be built into the AR process at organisational level. This could include providing sabbatical time to write up experiences. Otherwise, the researcher’s work may be included as part of a larger, envisioned programme of work.

All three of these strategies were used to ensure Dr Campbell, the external software developer and I did justice to the research goals. First, the bulk of the research was conducted after working hours. All three of us were all in gainful employment. Throughout my PhD degree, I was employed on a part-time basis as a clinical research analyst in DAPM. The external
software developer was employed on a full-time basis with an accounting software firm. Dr Campbell was employed as a specialist anaesthetist to care for publicly funded patients at Auckland Hospital and privately funded patients at Mercy Ascot Hospital. Our collective availability was limited so the bulk of the research (and practical problem solving) was conducted at weekends and after hours. Second, I was granted extended periods of leave to write up the research contribution that is this PhD thesis. I was fortunate enough to have a compassionate employer who, having completed his MD qualification, sympathised with my plight. Finally, I was able to incorporate the learnings from this research into my everyday practice at work. Although this thesis did not form part of a larger, formal programme of research, its research contribution improved my processes for interrogating HISs to obtain research datasets for other departmental projects.

Action researchers may also be inclined to overstate the importance of the AR intervention and the subsequent contribution to scientific research [458]. Oates [607] calls this phenomenon “self delusion and group-think”. She says that this danger arises because researchers want to show that the exercise is useful, and that their theory of method is valid. Heron [608 p. 146-148] recommends the rigorous use of a devil’s advocacy procedure to guard against this. For similar reasons, Baskerville and Wood-Harper [79] recommend enlisting a “dissociated watcher” who is charged with identifying misguided research assumptions, and Ainscow and Conner [609] suggest that action researchers enlist the help of a “critical friend”.

Throughout my PhD degree, I was fortunate enough to have an ally in Dr Johan Van Schalkwyk, a physician with a strong interest in medical informatics. Although he was not formally enlisted as a “dissociated watcher” or “critical friend”, Dr Van Schalkwyk was always on hand to challenge my thinking, to pose alternative courses of action and question whether I had considered the possibility of other influential factors. He directed me to relevant sources of literature and on one occasion asked me to provide a summary – my interpretation – of an article in the British Medical Journal authored by Berghmans and Schouten on the subject of Karl Popper’s principle of falsification [610]. We had many fruitful discussions over cups of coffee and via email on the subject of informed consent and risk assessment and communication. He was able to share a great deal of his experience as a clinician and that undoubtedly shaped my thinking throughout this journey.

3.7.3 Improving the rigour of PAR

Straub offers the following definition of rigour in the context of IS: “A term of art in IS and other social science research, specifically, a) the fitting of research methods to problems in
order to produce viable scientific explanations, b) the use of multiple methods and operationalisations in order or produce valid research constructs, c) the use of multiple methods in order to produce valid scientific explanations” [611 p. 104]. It follows that rigorous AR “clings tenaciously to its disciplined constructs of cyclical theoretical infrastructure, data collection and evaluation: there is a clear cycle of activity; there is a premise; a pronounced theory (under test); there is empirical data collection” [79 p. 241].

There exists a body of literature which emphasises the crucial importance of procedures to achieve rigour in IS AR (see [79, 80, 471, 524, 602, 606, 612, 613]). According to Dick [614], these procedures include multiple data sources, developing interpretations as part of the data collection process, accessing the relevant literature, creating dialectics, triangulating sources, and seeking out disconfirming evidence. Baskerville and Wood-Harper put forth a set of eminent strategies a researcher ought to consider to improve the rigour of their research of AR in IS [78, 79]. These include considering the non-positivist paradigm; establishing a formal research agreement; provision of a theoretical problem statement; planned measurement methods; maintaining strong collaboration and subject learning; promoting iterations; and restrained generalisation – though some of these procedures appear to be better suited to the formal, canonical forms of AR (see Davison et al. [613]) rather than the less formalised, more reflective and personal forms such as PAR (see Braa and Vidgen [492]).

Street and Meister [521] embed a number of these considerations in their research that culminated in an exemplary publication in the special issue on AR in MIS Quarterly [471]. The authors used PAR to investigate the development of an IS to address the growth needs of a small business management team. As part of their discussion, they put forth a set of desirable characteristics for AR based on Lincoln and Guba’s criteria for trustworthiness [579], with the aim of explicating the criteria by which readers might evaluate their PAR process. Drawing on these criteria alongside other prominent sources on rigour in IS AR, I have identified examples of the procedures we applied to ensure rigour in our PAR process (Table 18).
Table 18. Promoting rigour in our PAR process.

<table>
<thead>
<tr>
<th>Criterion for trustworthiness [579]</th>
<th>Desirable AR characteristics</th>
<th>Examples from this study</th>
</tr>
</thead>
</table>
| Credibility: Faithful descriptions or interpretations of a human experience that the people having that experience would immediately recognise it | • The observations are recorded and analysed in an appropriate frame [79]  
• Critical reflection on the social construction of data [460]  
• Viewpoints from multiple stakeholders are compared and contrasted [615]  
• Area of study, and the specific problem setting, are relevant and significant to researcher and participants alike [602, 613]  
• The research should be set in a multivariate social situation [80, 471]  
• Triangulation of information from multiple and varied data sources is used to establish credibility [613, 615]  
• Sufficient data must be collected to provide meaningful insight [79, 616]  
• Prolonged engagement is necessary to minimise distortions, to build trust and to learn the context [579]  
• Persistent observation for the purpose of identifying and assessing salient factors and crucial atypical happenings [579]  
• Changes in the social setting are analysed [80]  
• Researchers adopt an iterative, cyclical approach to problem solving [79, 602, 606, 613]  
• Roles and responsibilities of participants are explicitly stated [524, 602, 613]  
• Participants’ competency is expected to improve over time [602]  
• Peer debriefing, devils advocacy procedure, critical friend or dissociated watcher to improve validity if possible [79, 579, 609]  
• Negative case analysis [579]  
• Member checking [579]  
• Lack of functional distinction between the researched and researched [615] | • Continuous, co-generative dialogue between the external software developer, Dr Campbell and myself to create shared understandings, provide input into the emergent design and to ensure that all team members were apprised of “the next steps”  
• Diversity among anaesthetists’ risk communication practices was highlighted through the interpretive frame  
• Problem solving process led to research and practice contributions  
• Research was conducted entirely on-site, over a 2-year period, involving a small multidisciplinary group comprising of a specialist anaesthetist (Dr Campbell) and a clinical research analyst/PhD student with mentorship from the external software developer.  
• Data collection was regular and varied. Data sources included patient datasets, field notes, transcribed interviews, the hospital intranet site, emails, observations and reflections, presentation slides, comments and corrections on draft manuscripts.  
• New pieces of information were compared against other, previously collected data sources  
• Facts checked by those with first-hand knowledge particularly during the specifying learning phases.  
• Participants reflected upon the outcomes of the action taking within each cycle  
• Periodic no-holds-barred conversations with Dr Johan Van Schalkwyk kept me honest, and provided an opportunity for personal catharsis  
• Interviewees were asked for comment on output from previous interviews such that insights gleaned from one interview can be tested with another.  
• All anaesthetists were offered the opportunity to review their interview transcripts.  
• Dr Campbell, the external software developer and I were all viewed as researchers |
Table 18 (continued). Promoting rigour in our PAR process.

<table>
<thead>
<tr>
<th>Criterion for trustworthiness [579]</th>
<th>Desirable AR characteristics</th>
<th>Examples from this study</th>
</tr>
</thead>
</table>
| **Fittingness (Transferability): findings fit into contexts outside the study situation** | • The researcher is explicit about their use of theory [79, 524]  
• The research should delineate a theoretical framework that explains how the researcher’s and participant’s actions brought about a positive outcome [80, 471]  
• General concepts are used to explain the nature of the changes that occurred and why they might have occurred in such a way [460, 613]  
• The purpose of research is to grow the understanding of a problem  
• Restrained generalisation [79]  
• “Thick descriptions” are provided [579] | **Practical action was used to inform theory. Using Adams and Buetow’s framework, background theory [617] was used to frame the content of the local problem and translational theory provided the methodology to guide the intervention.**  
**The research led to the extension of the Multiview2 contingency framework for BI development.**  
**Research scope was broadened to include other anaesthetists in DAPM following the action taking phase of PAR cycle 1.**  
**Findings were considered with respect to implications for (1) further action in the current situation, (2) future action to be taken in related situations, (3) the research community and body of knowledge and (4) the general applicability of PAR [613]  
**Changes were introduced throughout the AR project to gauge their effect and usefulness, and to improve situational understanding. For example, we built and implemented the BI prototype, and then submitted it to the wider group of anaesthetists for informal feedback which provided the grounds for additional changes. We used learnings from each stage in later phases.**  
**The situation was assessed before and after the intervention within each PAR cycle.**  
**Dr Campbell, the external software developer and I were motivated to improve the situation and were all actively involved in problem solving activities to varying degrees.**  
**Planned actions were intended to solve the problem and improve the situation. Planned actions, such as change requests, were approved by Dr Campbell before they were implemented.**  
**I used I-mails [585] to record hunches, half-ideas, reflections and observations. Emails to self were also used to record software development decisions and track change requests.**  
**Informed consent was obtained from all interviewees prior to conducting interviews; written consent was obtained to use email correspondence; ethical and institutional approval sought.** |
| **Dependability (Auditability) when another researcher can clearly follow the “decision trail” used by the investigator** | • Future researchers can clearly follow the investigator’s “decision trail” [79, 602, 613] | **The research design and findings chapters provide a reliable audit trail. Systematic descriptions of participation are provided. Details include: the context of the research; project initiation and site “selection”; how many people were involved in the participation process; how often and over what period of time they participated in it; how the project parameters came to be; what data was collected, when, and by whom; and how these data were analysed.** |
| **Confirmability:** Engagement with the things to be known is sought in the interests of truth. Findings, interpretations and recommendations are supported by the data | • Research participants directly intervene in the research setting [80, 471]  
• Principle of interaction between researchers and subjects [460]  
• Researchers seek to engage actively with principal stakeholders [79, 615] | **Participant observation is used as one of the data collection techniques [80]  
Researchers develop an understanding of the context under study by observing the actual environment and the participants within it as they live and work [615]  
Ethical issues are identified and addressed satisfactorily [602]** |
To conclude this chapter, a summary of the research design is presented in Table 19. The intent is to highlight key aspects of the research design. These are presented alongside the corresponding dimensions in Lau’s [601] unifying IS AR framework, which provides criteria and questions that researchers ought to consider when designing and conducting AR studies in IS.

**Table 19. Summary of the research design.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Corresponding dimension in Lau [602]</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research paradigm</td>
<td>Perspective/tradition</td>
<td>• Pragmatic</td>
</tr>
<tr>
<td>Research method</td>
<td>Stream</td>
<td>• Interpretive</td>
</tr>
<tr>
<td>Data collection techniques</td>
<td>Data sources</td>
<td>• PAR</td>
</tr>
<tr>
<td>Data analysis techniques</td>
<td></td>
<td>• Semistructured interview</td>
</tr>
<tr>
<td>Ethical considerations</td>
<td>Ethics</td>
<td>• Field notes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Documents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Informed consent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ethics and institutional approval</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Anonymity and confidentiality</td>
</tr>
</tbody>
</table>

### 3.8 Conclusion

In this chapter, I have reviewed the philosophical assumptions underlying the pragmatist and interpretive paradigms that underpin this research. This was followed by a discussion of AR and more specifically PAR as the research method of choice. Data collection techniques that were employed as part of this method included the semistructured interview, field notes and documents, which were analysed using narrative and visual mapping, thematic analysis and the critical and illustrative case approach. Subsequent to this, the ethical considerations inherent in this research were highlighted and an overview of the common criticisms and limitations of the AR method was presented. The chapter concluded with a description of the practices and procedures that were employed to ensure a rigorous research approach. The research design described in this chapter was employed to solve the specific research problem. Briefly, the research problem suggests that the current BI capability in preoperative
care does not provide anaesthetists with sufficient actionable insights relevant to their own clinical settings in support of risk-benefit assessment before elective surgery. The research design was unpacked in detail to provide an understanding of the actions that were taken to solve this problem, which are detailed in the findings chapters that follow.
Chapter 4: Developing a BI prototype

4.1 Introduction

In Chapter 3, the methodological foundations of the thesis were outlined in order to establish a course of action for data collection and analysis. In this chapter, the findings from the first PAR cycle are presented (Figure 22). This cycle resulted in the development of a BI prototype, which presented anaesthetists with information about perioperative mortality at the point of care.

![Diagram of PAR cycles](image)

**Figure 22.** Data collection and analysis for PAR cycle 1.

Research in this cycle sought to address the first objective of this thesis: to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in the healthcare sector. Briefly, Multiview2 is a software development methodology that has been used for desktop and web application development, but not specifically for BI
development. Central to the framework is the idea that change agents draw on an interpretive scheme (Figure 23) in their struggle to develop and deploy IS in an organisational context. The features of Multiview2, namely its support for development that is contingent, even-handed and situated, suggested that the framework would be compatible with early development efforts in healthcare.

![Interpretive scheme](image)

**Figure 23.** The organisational analysis, information system modelling, and software development quadrants of Multiview2.

The methods used in the development of the BI prototype are presented using the four quadrants of the interpretive scheme (Figure 23). In this chapter, I present the work that Dr Campbell and I undertook in the organisational analysis, information modelling and software development quadrants of the Multiview2 methodology to build a BI prototype; our work in the sociotechnical analysis is discussed in Chapter 5. Consistent with Vidgen’s [533] approach, the aim is to contrast the indicative and stereotypical methods of Multiview2 with what actually occurred in practice to gain an insight into the appropriateness of the methodology for use in BI development. I begin this chapter with a review of the emergent content of the BI development framework and conclude with a summary of the findings from our work in the first three quadrants of the methods matrix.

### 4.2 Organisational analysis

Organisational analysis is the first of the four quadrants in the Multiview interpretive scheme. This activity permits the analyst to gain an appreciation of the work that the IS is to support [534]. Work in this quadrant looks at the organisation and its purpose and problems, with the aim of creating a shared understanding of what the IS will be and what it should do [4]. In
keeping with this definition, this section is structured as follows. First, Auckland City Hospital and DAPM are described. Second, I will describe how the shared understanding of what the IS will be and do emerged. Third, the indicative and stereotypical activities in the organisational analysis quadrant of Multiview2 are contrasted with what actually occurred in practice.

4.2.1 The organisational context
This thesis was carried out in DAPM at Auckland City Hospital within Auckland DHB. Auckland City Hospital is a 1,200-bed, university-affiliated tertiary facility. The hospital provides more than 20,000 elective surgical discharges per year, making it NZ’s largest healthcare and clinical research facility [21]. The provision of pre-, intra- and postoperative anaesthesia care for adult patients undergoing surgery at Auckland City Hospital is provided by DAPM. Anaesthesia services are provided for patients undergoing emergency or elective neuro-, vascular, urological, general and orthopaedic surgery across 11 elective and 2 emergency operating rooms on Level 8 of Auckland City Hospital. Anaesthetists in the department are involved in all aspects of patient care from assessing patients’ health prior to surgery at AAC based at Greenlane Clinical Centre and on the wards at Auckland City Hospital, to providing anaesthesia in the operating rooms and managing patients’ pain after surgery. At the time of this research, the department employed 55 consultant anaesthetists and a perioperative physician who were supported by 25 junior doctors to provide anaesthesia care and perioperative optimisation services to more than 10,000 patients per year. To support the anaesthetists in their day-to-day work, the department also employed two administrators and a functional application support analyst for the AIMS.

As part of their professional obligation, anaesthetists were responsible for documenting information about their delivery of clinical care to individual patients. Healthcare information was increasingly written, stored and accessed electronically. Referral letters, discharge summaries and other miscellaneous correspondence; laboratory and radiology results; admission, discharge and transfer events for care delivered within the DHB were all accessible via a clinical portal. Some of this information, such as laboratory test results, could be accessed electronically as soon as the results were made available. Patients’ nursing and medical notes, on the other hand, were handwritten during their hospital stay and subsequently scanned into the electronic record after hospital discharge.

Anaesthetists would routinely access the electronic medical record via the clinical portal to obtain information about a patient’s health status prior to (and sometimes during) the preoperative anaesthetic assessment. With the patient in the operating room, anaesthetists
recorded all drug and fluid administrations, drug allergies and adverse drug reactions and events (e.g. anaesthesia start/end) in the AIMS. Recovery and post-op instructions, and pain prescriptions were also entered into the system, printed and formed part of the handover to staff in the recovery room. Given the extent to which patient information was captured and stored electronically, all anaesthetists were proficient at using HISs to enter, edit, search and retrieve information for individual patients.

Obtaining information about groups of patients was not nearly so routine. The DHB had a small in-house team who were responsible for transforming data into actionable information to enable effective decision-making. At the time, the BI unit did not have a position that was specifically responsible for acting as liaison between the anaesthetists and their staff. DAPM was based on Level 8 at Auckland City Hospital and the BI unit was based on Level 2, Building 16, at the Greenlane site. Operating across separate sites left little room for opportunistic conversations about access to information and cross-pollination of ideas about its use. Instead, staff members in DAPM whose roles spanned both the IT and clinical spheres appeared to function as contact points. Ad hoc requests for data extracts required for clinical audit and research were routinely directed at a long-standing staff member who was employed to support the AIMS. This staff member had an office within the department and could often be found in the operating rooms responding to technical support requests. She was able to obtain information about the delivery of anaesthesia care from the AIMS quickly and without the need for specialist programming skills or reporting technologies. Avenues to access data from HISs that existed outside of the AIMS did not appear to be common knowledge among anaesthetists. Anaesthetists seemed to consider that information related to patient admissions, clinical coding, laboratory and diagnostic test results and patient discharges could be difficult to obtain. Ad hoc requests for information of this nature would often be facilitated by conversations with the staff member responsible for supporting the AIMS, who would in turn make contact with the appropriate analyst within the wider IT department. Most access to information, at least initially, was via informal channels within the department.

Beyond ad hoc requests for information, most anaesthetists did not appear to be familiar with the concept of BI. Across the organisation, BI seemed to focus on operational and financial reporting and this was likely due to limited resources and organisational priorities. This focus meant that there were few reports or dashboards at the time that were intended to be used by clinicians at the point of care. To compound this, anaesthetists seemed to think in terms of ad hoc requests for information rather than on-demand access to current information supplied via a report or dashboard. It was not unlikely that most anaesthetists did not know what data were
available, how to access them and, more generally, what was or was not technologically possible. Frontline staff did not always appear to make the connection between the capture of this information and the ability to use it in aggregate form at a later date. With the exception of clinicians who had formal postgraduate training in IT or organisational responsibilities that required liaison with the wider IT department, most anaesthetists were not socialised to the concept of BI.

Dr Campbell and I decided to attempt to build an initial BI prototype within DAPM. There were two key drivers for this decision. First, the act of building a prototype within the department allowed staff outside of the BI unit to develop a degree of understanding of the wider ISD and the challenges, opportunities and decisions that may need to be made along the way. The prototype was seen as a learning and research opportunity, and as a way of enabling us to make plain the relationship between data capture in the operating rooms and access to this data in aggregate form at the point of care. In developing this understanding, we hoped to pave the way for future work of this nature. Second, building a prototype within the department afforded us the opportunity to “do our homework”. We wanted to be certain that a prototype would be useful in the clinical setting before approaching the BI unit to assist with a full-scale development. Our decision was by no means a criticism of the BI unit or its staff. Rather, it afforded the opportunity for a clinical department to own the exploratory work, to become familiar with key development concepts and data structures and to start to piece together the puzzle on their own terms. By doing so, we believed we could develop an appreciation of the role of the BI unit, the skill and expertise required of its staff and the challenges and opportunities that this sort of work presented, which would all be key to engaging the unit for future development.

4.2.2 Developing a shared understanding of the IS
A shared understanding of what the BI prototype would be and would do emerged through informal conversations I had with Dr Campbell that began during the course of our everyday work in March 2011. These conversations occurred both face to face and via email, and frequently included other interested clinicians in the department. Through these conversations I came to understand the need for a system to get better access to our (the institution’s) own information at the point of care. There were many conversations about the difficulties inherent in generalising from international research to local patient populations, particularly as they relate to the discussion of the risks and benefits of surgery. To add to this, data on perioperative outcomes specific to the cohort of patients cared for at the institution seemed to
be largely invisible to anaesthetists during the preoperative anaesthetic assessment. During one of these conversations, Dr Campbell commented that:

*Toyota can tell me how many cars they’ve made and I can’t tell you how many of our patients have died after surgery.* (Informal conversation with Dr Campbell, 2011)

In essence, this comment spawned the project and became the platform from which to frame the problem situation – that anaesthetists did not have sufficient, actionable insights relevant to their own clinical settings in support of risk-benefit assessment before elective surgery.

From these conversations, the organisational analysis surfaced: (1) to gain actionable insights into perioperative outcomes for patients undergoing elective surgery in the care system that generated the data, and (2) to make these insights available to anaesthetists at the point of care to support risk-benefit assessment and communication during the preoperative assessment.

The organisational analysis is illustrated in the following excerpt:

*The idea is to have simple data to inform patients about local outcomes. I would like to be able to tell an ASA 3 pt [patient] having intermediate severity colorectal surgery your likely mortality is . . .%.* (Email communication from Dr Campbell to senior physician, anaesthetists and myself, June 2011)

As part of the organisational analysis, Dr Campbell and I decided that the project should focus solely on mortality at 30 days and 1 year after surgery, rather than any number of non-fatal perioperative events. This decision warrants explanation. Prior conversations between Dr Campbell and another senior anaesthetist in the department, and between Dr Campbell and staff members in the clinical coding department several years earlier, provided insight into the imperfect way in which surgical complications are recorded. Information about the incidence of major complications, including infection, myocardial infarction (MI) and pulmonary embolism (PE) or deep vein thrombosis (DVT) after surgery, while valuable, could be misleading if the quality of data could not be assured. Uneasiness about the quality of this data is evident in the following sentiment from a senior physician to Dr Campbell and myself:

*Unless you are putting a lot of effort into collecting data about infection, MI, DVT and PE prospectively, any retrospective data will likely be worse than useless (i.e. misleading). Death is a different story, so this is the logical endpoint to focus on.* (Email communication from senior physician to Dr Campbell, senior anaesthetists and myself, June 2011)

During the course of reviewing the literature, I found several articles that provided a solid foundation to support our decision. The following is an excerpt from the literature review I conducted, outlining the reasons for continued reporting of mortality after surgery and specifically, the suitability of RCD for this purpose:
Death after surgery affects a small, but important, number of patients who undergo elective surgery [618]. Although overall mortality in the perioperative period is low [619], it remains an important clinical outcome because of the high number of procedures performed worldwide [336]. The absence of mortality from a dataset of perioperative outcomes has implications for the credibility (face and content validity) of the dataset [184]. Surgical mortality describes an unambiguous event that is clinically relevant, for which the data are commonly recorded and widely reported [54, 184, 421, 620, 621]. RCD are well suited to measuring surgical mortality and other such outcomes that rest on programmatic transformation of dates and types of service [622]. (Excerpt from literature review, 2011)

The collective decision to restrict the scope of the build to include mortality rather than morbidity was made on the proviso that we would expand the prototype to include estimates for other non-fatal complications if the data quality could be assured. With the client organisation described, as well as how a shared understanding of the IS emerged, the following subsection will relate our organisational analysis to the Multiview2 methods.

4.2.3 Organisational analysis in the context of the BI prototype

The primary methods for organisational analysis in Multiview2 are SSM [560, 576, 623] and stakeholder analysis [561], as described in Vidgen [548]. SSM is used to structure thought concerning the problem situation and to realise an accommodation – an agreement about what action should be taken to change the problem situation [548]. To supplement SSM, stakeholder analysis is often used to cater for pluralism. Flood and Jackson [624 p. 34] (after Burrell and Morgan [625]) define pluralism as a “situation in which stakeholders are perceived to have a basic compatibility of interests; not necessarily agree on ends and means, but be able to achieve compromise; act in accordance with an agreed objective; and have some divergence of values and beliefs”. Both SSM and stakeholder analysis are stereotypical methods used in the organisational analysis quadrant in Multiview2.

SSM and stakeholder analysis are especially relevant in complex situations and those characterised by pluralism of stakeholder interests [624]. By contrast, the BI prototype was perceived by Dr Campbell and myself to be systemic-unitary. Stakeholder interests were unitary insofar as Dr Campbell and I were in agreement on both the ends – success would be measured by the ability to access information about perioperative outcomes for patients undergoing elective surgery in the care system that generated the data – and the means. Although the potential for pluralism of stakeholder interests in future development cycles may have emerged, Dr Campbell and I were in agreement as to the common goals of the project and decisions were made in accordance with these goals. In addition to the type of decision-makers involved, the nature of the system is also is thought to have an important effect on the
character of the problem and therefore the methods used to solve it [572]. The perioperative care system that generated the RCD for the project was only partially observable; was considered to be open to its environment; and was comprised of purposeful parts that were undoubtedly subject to behavioural influences [572]. As with much of healthcare work, we knew that the system was likely to be characterised by distributed decision-making, multiple viewpoints, and by the inconsistent and evolving knowledge bases [626] of all involved. On this basis, we did not anticipate that the system would be straightforward to analyse. Based on Jackson and Keys’ classification of problem contexts and alignment with problem-solving methodologies [572] and our shared perception that the ISD was an exploratory exercise to assess viability or usefulness, employing systems thinking in SSM would not have been considered to be meaningful. To employ SSM in a systemic-unitary context would have been considered inefficient because resources would be wasted in reaffirming an already existing consensus on objectives [572]. Instead, organisational analysis was conducted informally. Through a literature review of international standards for reporting of perioperative events and email communication and informal discussions between Dr Campbell, other clinicians in the department and myself, the organisational analysis emerged:

My primary interest initially was clinically focussed . . . to get better local clinical data into clinician’s hands so they are able to use local information to express risk with a degree of appropriate statistical certainty. (Email communication from Dr Campbell to myself, February 2012)

In the Multiview2 methods matrix, organisational analysis can be seen, more generically, as orientating. SSM and stakeholder analysis have traditionally been applied to this activity, such that a systemic transformation creates benefit for a client and the pluralism of stakeholder interests is acknowledged. In the context of the BI prototype, Dr Campbell and I were orientating to a set of unique objectives and developing a shared understanding of the value-add, criteria for measuring success, assumptions and constraints, all of which came together as a plan of action. Although this is not considered “below the line” thinking [593] in SSM insofar as our work yielded neither a root definition of relevant systems nor a conceptual model of these systems, the aim of organisational analysis is to gain insight into purposeful activity and meaningfulness [533], which in the context of the BI prototype could be broadly constituted as orientating to develop an understanding of the organisation, the problem situation and, as part of this, developing a plan of action.

4.3 Information system modelling

The project continued with the evolutionary process of information modelling. By definition, work in this quadrant seeks to develop a technical representation of the proposed IS using
object-oriented analysis and business process modelling techniques [534]. In the context of the ISD, our work in this quadrant sought to develop a representation of the as-is source systems that might serve as a load source for the prototype (represented in blue in Figure 24) and the BI prototype itself (represented in green in Figure 24). For clarity, our work in this quadrant can be thought of in three distinct parts. We carried out work to (1) identify potential source systems, (2) learn about the structure, content, relationships and derivation rules of these systems, and (3) select attributes from these systems for inclusion, based on these investigations.

In keeping with this thinking, this section is structured as follows. First, the identification of potential source systems is described. As part of this section, I include an overview of the relationship between the patient journey to elective surgery and the data captured in these source systems to help the reader understand this work. Second, the work to understand the structure and content of the source systems is described. Third, the attributes that were selected from each of these systems are reviewed and the rationale for their inclusion is provided. Finally, the set of activities is contrasted with the indicative and stereotypical activities in the information modelling quadrant of the Multiview2 framework.

![Information system modelling](image)

**Figure 24.** Information system modelling for the BI prototype project.

### 4.3.1 Identifying potential source systems

Our work in the information modelling quadrant began with the identification of source systems to serve as a load source for the BI artefact. As regular and proficient users of HISs, Dr Campbell and I were able to readily identify three potential load sources for the prototype: the PAS, PIMS and AIMS. Details of these systems are provided in Table 20. The PAS was
implemented in the late 1990s, the PIMS was first implemented in November 2002, and the AIMS was first implemented in May 2005. The PIMS and AIMS both interfaced with the legacy PAS. With respect to systems functionality, the PAS was used to record patient demographic information and inpatient stays, discharges and transfers for individual patients. The PIMS provided functionality to schedule theatre sessions and to allocate surgeries to these sessions. This system also included functionality for theatre nurses to record their perioperative nursing care. Finally, the AIMS allowed anaesthetists to record all drug administrations during an anaesthetic using either barcode scanning of specific drug labels on syringes or via manual entry via a keyboard.

Table 20. Functional descriptions of three key HISs.

<table>
<thead>
<tr>
<th>System</th>
<th>Period implemented</th>
<th>Functionality</th>
</tr>
</thead>
</table>
| PAS    | Late 1990s         | • Record patient demographic data  
• Record inpatient stays (including intensive care), transfer and discharge events for individual patients |
| PIMS   | November 2002      | • Schedule theatre sessions and allocate elective and emergency surgeries to operating rooms  
• Record intraoperative details including the name and code for the surgical procedures performed, duration and urgency of the surgery, complications, surgical service responsible for performing the surgery and the outcome of the procedure, including whether the surgery was cancelled, completed or abandoned  
• Record preoperative and recovery room clinical details including complications |
| AIMS   | May 2005           | • Record the time, drug, and dose of administered anaesthetic medications  
• Record basic details about the patient’s medical history |

Before delving into details of how we set about learning the structure and content of these systems, due to the complexity of the work it is first necessary to understand the relationship between the patient’s pathway for elective surgery and the points at which data are captured in these systems. The relationship between these two aspects is presented in Figure 25. For clarity, there are many alternate and exception flows for this process that are not depicted in the diagram. For example, a patient may be exempt from day-of-surgery admission and instead be admitted to the surgical ward before surgery for additional preoperative procedures that require hospital admission. Similarly, a patient undergoing high-risk surgery may be admitted to the high dependency unit or ICU instead of PACU, and only be sent to the surgical ward for the remainder of their admission at a later date. For the sake of simplicity, these flows are not represented in Figure 25.
Figure 25. The perioperative care pathway and associated data capture in HISs.

With reference to Figure 25, the high-level patient and information flows are as follows. Before undergoing elective non-cardiac surgery, patients are admitted to the Operating Room Day of Admission (ORDA) area on Level 8 of Auckland City Hospital. This event is shown in dark blue in Figure 25. On arrival, an administrator checks the patient’s details including their name, address and GP, and amends or updates these in the PAS if required. After the demographic details are confirmed, the patient is prepared for surgery by one of the nurses working in ORDA. Details of medications administered and observations such as blood pressure, weight and temperature are recorded by hand in the patient’s hard-copy medical notes which are kept in a folder for the duration of the patient’s hospital stay. At this time, the nurses may also enter important information about the timeliness of key preoperative events under the pre-op/PACU tab in the PIMS, such as when the patient was sent for from the ward or other area by theatre staff (Figure 26).
After meeting with members of the surgical and anaesthetic teams in ORDA and signing the necessary consent forms, the patient is taken through into the operating room. This event is shown in green in Figure 25. Once in the operating room, a series of checks are completed, after which anaesthesia and surgery will begin. Whilst the patient is undergoing surgery, a theatre nurse will enter important information into the PIMS including the date and time the patient arrived into the operating room, the date and time the anaesthetic was administered, and when the procedure started. Theatre nurses also record other pertinent details, such as the outcome of the surgery, the procedures that were undertaken and any equipment or implants that were used during surgery. These details are all entered under the “In-theatre Details” tab (Figure 27).

Figure 26. “Sent for” and “Arrived” timestamps under the “Pre-op/PACU Details” tab of a patient record in the PIMS.

Figure 27. “In-theatre Details” tab of a patient record in the PIMS.
At the same time as the theatre nurse is entering data into the electronic intraoperative record in the PIMS, the anaesthetist is recording information about the administration of the anaesthetic in the AIMS. A screenshot from the AIMS training module in the orientation pack for new registrars demonstrating some of the fields in the AIMS is shown in Figure 28.

![Figure 28. Screenshot from the AIMS training module in the registrars’ orientation pack.](image)

Information including the patient’s surname, first name, date of birth, surgery, operating theatre and surgeon is brought through from the PIMS. The anaesthetist checks these details and fills in other relevant data, such as weight, height, ASA score, clinically significant drug allergies and key events such as anaesthesia start time, on the screen during a stable period of anaesthesia. The anaesthetist draws up the necessary medications and labels the syringes with colour-coded, easy-to-read labels. These syringes are scanned prior to drug administration using a barcode reader attached to the anaesthetist’s computer in the operating room and this action enters a drug administration event into the electronic anaesthetic record in the AIMS.

With surgery complete, the patient is transferred to PACU to recover. This event is shown in light blue in Figure 25. At the end of the case, the intraoperative record from the PIMS, the anaesthetic record and postoperative medications and fluid orders from the AIMS are printed and filed inside the patient’s folder with the remainder of their medical records for the admission. The nurses in the PACU append handwritten notes about their nursing care to the patient’s paper-copy medical record and capture important information about the timeliness of key postoperative events under the “PACU” section of the “Pre-op/PACU Details” tab in the PIMS (Figure 29). The patient and information flows were found to be similar to those described earlier in the literature review in Chapter 2.
4.3.2 Learning about the source systems

After identifying the PAS, PIMS and AIMS as potential sources of information for the BI prototype, I commenced a stream of work to learn about these systems. More specifically, I sought to dig into the deeper layers of the data in these systems to learn about their structure, content, relationships and derivation rules. To do so, I required access to the reporting databases for the AIMS, PIMS and PAS. The reporting databases seemed a logical place to start the discovery because the persisted data were identical (or almost identical) to those data stored in the live source systems. The request for access was made via the appropriate channels and access was granted to all three reporting databases in May 2011. After receiving access, I recovered and reconstructed the functional and technical specifications of the PAS, PIMS and AIMS as best I could. I employed Tilley’s [627] support mechanisms to aid program understanding – the process of acquiring knowledge about existing, generally undocumented IS. Tilley’s support mechanisms include the use of computer-aided techniques, unaided browsing and leveraging corporate knowledge and experience to develop an understanding of the HIS.

Figure 29. “PACU” timestamps under the “Pre-op/PACU Details” tab of a patient record in the PIMS.
I used computer-aided techniques to understand the physical structure of the systems. ERWin® Data Modeler (Ca Technologies, Tampa, FL) was used to reverse engineer physical data models of the persistent structure of the PAS and PIMS (Figure 30).

![Figure 30. Exploring the PIMS with ERWin® Data Modeler.](image)

Through the process of reverse engineering, I obtained a representation of the static properties that are defined in a schema. The schema consisted of a definition of all database objects, including tables and their attributes, relationships and constraints. The schema for the AIMS was provided by a contact at the vendor. After generating or acquiring the physical models, I annotated and pinned them to the office wall. To simplify these models, I maintained rough sketches of the relationships between the physical implementation of the systems and the data displayed in the user screens. I also kept boilerplate code that referenced frequently used identifiers and attributes, as well as I-mails [585] to reflect on any problems encountered accessing or manipulating data. Throughout this process, I worked closely with Dr Campbell and another senior physician in DAPM who had postgraduate IT training and an interest in what we were doing. I shared my findings with Dr Campbell, as did the physician with me. As evidence of this collaboration, Figure 31 depicts a portion of the simplified schema provided via email by this physician. I used this diagram as a quick go-to for understanding the key tables in the PIMS and the relationships that existed between them.
In conjunction with the physical models, I used unaided browsing to create a representation of the dynamic properties of the systems. These properties can be thought of as specifications for queries and reports [628]. Unaided browsing involved scanning the source code (principally stored procedures with some functions) in the relational database management system, using the tree structure as a navigation aid. I also integrated alternative sources of data including in-line and block comments and source-code naming conventions. In this way, I was able to achieve a balanced understanding of the “whole” of each system by focusing on different artefacts and relationships [628]. Through the combined use of computer-aided techniques and unaided browsing, I obtained a representation of the system that comprised two components: static properties that were defined in the schema and dynamic properties that came in the form of specifications for queries and reports.

The ongoing process of leveraging corporate knowledge and experience was integral to understanding the physical models. I had developed close working relationships with contacts in the IT department who, having worked with the systems for a number of years, were able to validate and resolve any inconsistencies I encountered. Through email and phone contact with these personnel, I gained an understanding of how the systems had evolved over time. I obtained information about why the systems were implemented the way they were, the major changes that had occurred over their life cycle, unresolved bugs, and invaluable knowledge.
about the application domain. On many occasions, I received information about the location of a specific data point when source-code naming conventions did not throw up any light. For example, email communications with one of the functional application support analysts shed light on the location of “estimated blood loss”. It transpired that the data was stored as a locally defined field “USSOB_68” in a table named “LDD_LOCAL_DATAVALUES”. Communications with staff who had worked on and with these systems for extended periods of time ensured that I did not miss the big picture behind the evolution of the systems by focusing only at the low levels of abstraction provided by computer-aided techniques and unaided browsing [629].

4.3.2.1 A worked example: The ASA score

As part of the work to learn about the source systems, I set about verifying that various pieces of data were in a useable state and, as part of this work, made an assessment of their content, consistency and structure. Simple Structured Query Language (SQL) “SELECT” statements with “COUNT”’s and “DISTINCT”’s were used to provide invaluable information about the spectrum of values stored within each field, the extent to which “NULL” values were present, and to get an overall feel for the flavour of the data. Although work of this nature was carried out for a number of individual attributes, I focus here on the work that was undertaken to determine the source, and assess the consistency, of the ASA score.

The ASA-PS classification system (ASA score) [191-193] is a widely used score to assess the physical status of patients before surgery. The score was discussed in detail in Chapter 2, but salient points will be repeated here for context. In its current form, patients are assigned a score on a six-point ordinal scale prior to surgery, where class I indicates a fit and healthy patient and class V is reserved for a moribund patient who is not expected to survive without surgery. Class VI is used to designate organ retrieval in brain-dead patients and addition of the postscript “E” is used to indicate emergency surgery [37, 180]. Before surgery, the score is recorded on the hard copy anaesthetic assessment form when the patient is seen for their clinic appointment. Intraoperatively, the score is recorded by the theatre nurse in the PIMS and also by the anaesthetist in the AIMS.

The use of queries to profile the ASA score in the PIMS and AIMS yielded missing ASA scores and discrepancies between the two electronic sources. After conferring with Dr Campbell about the extent and nature of the missing data, the initial decision was made to source the ASA score from the PIMS. Our reasons for this were twofold. First, there were fewer missing values (6.9% missing ASA scores in the PIMS compared with 45.0% missing ASA scores in the AIMS). Second, the data had been captured since November 2002 in the
PIMS and only since May 2005 in the AIMS, so choosing to source the ASA score from the PIMS gave us a greater number of data points to include. This decision was made on the basis of high-level “COUNT”s of missing and discrepant ASA scores and was deemed an appropriate course of action to (1) minimise the amount of incomplete data and (2) maintain simplicity of development.

At a later stage in the project, we enlisted the expertise of a statistician to help to assess the agreement between nurse-entered ASA scores in the PIMS and anaesthetist-entered ASA scores in the AIMS to validate our decision. I was aware of previous literature that had used Cohen’s kappa score [630] to assess the extent of agreement (termed intrarater reliability [630]) among data collectors of the ASA score [631]. Our approach to assessing intrarater reliability would likely be similar to that adopted by Ragheb and colleagues [631] in their paper on the assessment of intrarater reliability of the ASA score in paediatric surgical patients. I sent that article to the statistician via email and, together with Dr Campbell, we met in person to discuss the approach to analysis. The statistician and I agreed that the intrarater reliability could best be analysed using weighted ($K_w$) and unweighted ($K_{uw}$) Cohen’s kappa. $K_w$ could be used for ordinal data so that the order of the ASA categories was taken into account. Using $K_w$, small differences between the categories (e.g. a nurse enters ASA4 and an anaesthetist enters ASA5 for the same patient) would contribute less to the overall $K_w$ than large differences between categories (e.g. a nurse enters ASA1 and an anaesthetist enters ASA5 for the same patient). With an analysis approach agreed, a cross-tab of the nurse-entered and anaesthetist-entered ASA scores was constructed. The level of agreement is described as per cent agreement and, as anticipated, was evaluated with kappa statistics. The findings of this analysis are presented in Table 21. We found that for patients whom:

- the nurse coded ASA1 and the anaesthetist also coded, the anaesthetist coded 85.6% of these also as ASA1, 12.6% of these as ASA2, 1.5% of these as ASA3, 0.2% of these as ASA4 and 0.1% as ASA5

- the nurse coded ASA2 and the anaesthetist also coded, the anaesthetist coded 89.6% of these also as ASA2, 4.8% of these as ASA1, 5.4% of these as ASA3, 0.2% of these as ASA4, and 0.0% as ASA5

- the nurse coded ASA3 and the anaesthetist also coded, the anaesthetist coded 88.4% of these also as ASA3, 0.5% of these as ASA1, 8.7% of these as ASA2, 2.4% of these as ASA4, and 0.1% as ASA5
• the nurse coded ASA4 and the anaesthetist also coded, the anaesthetist coded 84.4% of these also as ASA4, 0.3% of these as ASA1, 1.4% of these as ASA2, 13.0% of these as ASA3, and 1.0% as ASA5

• the nurse coded ASA5 and the anaesthetist also coded, the anaesthetist coded 71.7% of these also as ASA4, 0.9% of these as ASA2, 4.4% of these as ASA3, and 23.0% as ASA4.

The $K_w$ statistic was 0.899, suggesting almost perfect agreement between ASA scores entered by nurses in the PIMS and anaesthetists in the AIMS.


<table>
<thead>
<tr>
<th>Nurse-entered ASA score in PIMS (n, %)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16277 (85.6%)</td>
<td>2389 (12.6%)</td>
<td>285 (1.5%)</td>
<td>42 (0.2%)</td>
<td>16 (0.1%)</td>
</tr>
<tr>
<td>2</td>
<td>1248 (4.8%)</td>
<td>23160 (89.6%)</td>
<td>1392 (5.4%)</td>
<td>46 (0.2%)</td>
<td>2 (0.0%)</td>
</tr>
<tr>
<td>3</td>
<td>88 (0.5%)</td>
<td>1620 (8.7%)</td>
<td>16455 (88.4%)</td>
<td>441 (2.4%)</td>
<td>12 (0.1%)</td>
</tr>
<tr>
<td>4</td>
<td>9 (0.3%)</td>
<td>47 (1.4%)</td>
<td>447 (13.0%)</td>
<td>2902 (84.4%)</td>
<td>35 (1.0%)</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1 (0.9%)</td>
<td>5 (4.4%)</td>
<td>26 (23.0%)</td>
<td>81 (71.7%)</td>
</tr>
</tbody>
</table>

$K_{uw} = 0.824; K_w = 0.899$

We also assessed the interrater reliability of the urgency of the surgery. To capture the urgency of the surgery, theatre nurses complete the “Operation Type” field in the PIMS and the anaesthetists append the ASA score with an “E” for emergency procedures. Although the “Operation Type” was generally thought to be accurate, we sought to determine the extent of any discrepancy between the “Operation Type” and the anaesthetists’ entry of the ASA score. The findings from this analysis are shown in Table 22. We found that for patients whom:

• the nurse coded the surgery as “Acute”, 72.8% of the ASA scores entered by the anaesthetist in the AIMS were appended with an “E” and 27.2% were not

• the nurse coded the surgery as “Elective”, 4.2% of the ASA scores entered by the anaesthetist in the AIMS were appended with an “E” and 95.7% were not.

The $K_{uw}$ statistic is 0.714 suggesting strong agreement between emergency status entered by nurses and anaesthetists.

<table>
<thead>
<tr>
<th>Nurse-entered acuity in PIMS (n, %)</th>
<th>+“E”</th>
<th>““E”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>19147 (72.8%)</td>
<td>7171 (27.2%)</td>
</tr>
<tr>
<td>Elective</td>
<td>1817 (4.2%)</td>
<td>41391 (95.8%)</td>
</tr>
</tbody>
</table>

$K_{kw} = 0.714$

These findings suggested that, in general, assignment of the ASA score and urgency was reliable. There was strong agreement between emergency status entered by nurses and anaesthetists and almost perfect agreement between ASA scores entered by nurses and anaesthetists. The lowest interrater agreements were for assignment of emergency status (72.8%) and for ASA5 scores (71.7%), respectively. This finding was not unexpected. Patients assigned an ASA5 score are, by definition, emergency cases that are not expected to survive without surgery. Under these circumstances, it is not unreasonable to suggest that the accurate capture of the ASA score is likely to fall secondary to the provision of critical patient care.

Despite the findings, I sought to understand the possible reasons for the discrepancy. By way of informal conversations with theatre nurses and functional application support analysts, I came to understand that the practice of theatre nurses was either to ask the procedural anaesthetist for the ASA score or to look up the score on the paper-based anaesthetic assessment form in the patient’s medical notes before entering the score into the PIMS. However, the anaesthetist may change the ASA score part way through the surgery and these changes are not always reflected in the PIMS if the change is not communicated to the theatre nurse. Alternatively, theatre nurses may use the “down” arrow on the keyboard after selecting the ASA score from the dropdown list to move to the next field under the “In theatre” tab in a patient’s record in the PIMS. Unlike other HISs, the PIMS does not allow the down arrow to be used in this way and instead selects the next ASA score from the list. If the nurse is unaware that this has occurred, the incorrect ASA score is recorded. With respect to the urgency of the surgery, the theatre nurse educator suggested that some theatre nurses were unclear about whether the appended “E” on the ASA score was used by anaesthetists to signal emergency or elective surgery. Compounding this, the default surgery type in the PIMS is “elective”, so on occasion nurses may forget to change it to denote an emergency surgery. Hence, small discrepancies between the ASA score in the AIMS and the type of surgery in the PIMS existed.
As part of the work to gauge whether the ASA score was in a useable state, I also assessed the extent of missing ASA scores. Over the course of the investigations, I had encountered instances in which the ASA score in the PIMS retained the default value of “NSP” (Not specified) or, in the case of the AIMS, was left blank. To assess the extent of the missing data, the statistician and I examined ASA scores recorded in both the AIMS and PIMS. The findings from this analysis are presented in Table 23. We found 8,707 (6.9%) intraoperative records in the PIMS with an ASA score listed as “NSP” and 56935 (45.0%) intraoperative records in the AIMS with a “NULL” ASA score between November 2005 and October 2012. A total of 6,207 (5.2%) intraoperative records did not have an ASA score recorded in either the PIMS or the AIMS. On further investigation, more than three-quarters of those records without an ASA score in either the PIMS or AIMS were associated with minor surgeries that did not require a general and/or regional anaesthetic such as excision of small skin lesions and biopsies of skin or subcutaneous tissue. The proportion of records in the AIMS with a missing ASA score also appeared to decrease over time. The highest proportion of missing ASA scores was recorded in 2006, with almost 5,000 procedures without an ASA score. By 2012, this figure had almost halved.

<table>
<thead>
<tr>
<th>Nurse-entered ASA score in PIMS (n, %)</th>
<th>Anaesthetist-entered ASA score in AIMS (n, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>ASA1-5+/−E</td>
</tr>
<tr>
<td>NSP</td>
<td>6207 (71.3%)</td>
</tr>
<tr>
<td>ASA1–5</td>
<td>67026 (56.9%)</td>
</tr>
<tr>
<td></td>
<td>2500 (28.7%)</td>
</tr>
<tr>
<td></td>
<td>50728 (43.1%)</td>
</tr>
</tbody>
</table>

Again, recognising that frontline staff will often know more about potential data quality problems than I could ever hope to understand with simple “SELECT” statements, I set about seeking answers from theatre staff and anaesthetists to understand the nature of the missing ASA scores. Through informal conversations, it become apparent that the cause of the missing data was multifactorial. Some staff did not appear to relate the capture of this information to its use at a later date. This sentiment was highlighted in one of my reflection notes after a conversation about missing ASA scores with an anaesthetist who held a concurrent role in quality assurance:

*She commented that she hadn’t thought about the importance of entering the ASA score into the AIMS until she required the data for research or QA purposes.*
Conversations with the theatre staff also identified systems design and human error as a potential cause for the missing data. The ASA score was not a mandatory field in either the PIMS or the AIMS. In the PIMS, the field is pre-populated with the default value “NSP”. Theatre nurses may on occasion forget to change the default ASA value from “NSP” to reflect the physical health state of the patient. With so many fields pre-populated with default values, it was often difficult to see at a glance what information had been entered by the theatre nurse and what information was still outstanding.

Following this analysis, we continued with our decision to use the ASA score in the PIMS and chose not to substitute “NSP” ASA scores from the PIMS with those from the AIMS for the sake of simplicity. We did, however, change our decision at the point of statistical analysis (discussed in Chapter 6). If there was an inconsistency in the ASA scores recorded in the PIMS and the AIMS, the score coded by the anaesthetist in the AIMS was used. In hindsight, although the kappa statistics confirmed almost perfect agreement between the nurse-entered and anaesthetist-entered scores, this decision appeared to better reflect the nature of the score as a measure assigned by an anaesthetist. A summary of our investigations and decisions with respect to the ASA score as they related to the development of the BI prototype is presented in Table 24.
Table 24. Data quality issues, investigations, and actions for the BI prototype.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Investigation</th>
<th>Key findings</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagreement between nurse entered ASA</td>
<td>Inconsistent data</td>
<td>% agreement, $K_{uw}$ and $K_{w}$ scores to assess interrater reliability</td>
<td>• Analysis found almost perfect agreement between ASA scores and strong agreement between emergency status entered by nurses in PIMS and entered by anaesthetists in AIMS.</td>
<td></td>
</tr>
<tr>
<td>score in PIMS and anaesthetist entered ASA</td>
<td></td>
<td>and informal conversations with theatre staff to elicit practice</td>
<td>• Disagreement could be attributed to human error, poor information system</td>
<td>Decision made to source ASA score from PIMS</td>
</tr>
<tr>
<td>score in AIMS</td>
<td></td>
<td></td>
<td>design and inadequate training.</td>
<td></td>
</tr>
<tr>
<td>ASA scores are not specified</td>
<td>Missing data</td>
<td>Descriptive statistics and informal conversations with theatre staff to elicit practice</td>
<td>• ~5% of records without an ASA score in either PIMS or AIMS.</td>
<td>Exclude records without an ASA score</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Fewer missing ASA scores in PIMS compared with AIMS for the same time period.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• ASA scores missing from both PIMS and AIMS mostly corresponded to minor procedures not performed under general+/– regional anaesthesia</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Disagreement could be attributed to human error, poor IS design and an inability to relate information capture at point of care to its use in aggregate form at a later date.</td>
<td></td>
</tr>
</tbody>
</table>

4.3.3 Selecting attributes for inclusion

The remainder of the work in this quadrant focused on selecting attributes for inclusion into the feed for the BI prototype. Through a series of iterations to research and profile the data sources, Dr Campbell and I agreed on the attributes that would be loaded, the source for these attributes, and the inclusion and exclusion criteria. We knew that not all attributes within the source systems would be required for the project. McKee’s conceptual model of the information required to describe the outcome of an intervention using RCD [391] provided me with a useful way to articulate our work. According to McKee, information is required to describe interventions, patients and outcomes. In the context of the BI prototype, baseline clinical and demographic information about patients prior to surgery is required to ensure that comparable persons are analysed [622]. This requirement is represented as the measurement of preoperative health state shown in Figure 32. In addition, key characteristics about surgery
and anaesthetic management, along with other confounding variables that may influence the outcome/s of interest are also required. This requirement is represented as the measurement of intervention. Lastly, data about the occurrence (or not) of the outcome of interest must also be collected. This requirement is represented as the measurement of outcome. With these criteria in mind, Dr Campbell and I selected data to fulfil each of these categories based on clinical judgement and a review of the literature. These data are considered in the following subsections, beginning with the measurement of outcome.

![Diagram showing the measurement of outcome](image)

**Figure 32.** Information required to describe the outcome of an intervention using RCD. Adapted from McKee [391].

### 4.3.4 Measurement of postoperative outcome

Mortality after surgery was the outcome of interest. It is widely reported, describes an unambiguous event, and the data needed to calculate it are readily available [54, 421, 620, 621]. Mortality can be defined as a temporal measure (e.g. mortality within 30 days of surgery) or according to the location of a patient at the time of the event (e.g. in-hospital mortality) [184]. However, in reviewing the literature, many studies use specific cohorts of surgical patients (e.g. cardiac, vascular or transplant), limited hospital participation and variable reporting timeframes [632]. Large studies of perioperative mortality, for example, have reported deaths during surgery [633]; in-hospital [634, 635]; within 24 hours [636, 637]; within 2 [189], 3 [638], 6 [639], 7 [125, 640] or 30 days [151, 641] and up until 6 weeks after surgery [642]. Variation in defining and calculating perioperative mortality affects the
timeframe for which deaths are recorded and subsequently reported [32, 58, 620], making it difficult to generalise findings from studies in other countries, regions or hospitals.

In the absence of a standard definition of mortality after surgery [32, 58, 620], we estimated all-cause 30-day and 1-year mortality. Timeframes beyond 30 days after surgery will likely capture mortality from multiple causes, but there is a growing body of evidence to suggest that a high percentage of postoperative complications and deaths occur after 30 days postoperatively [244], so these data may be used to provide useful risk information to patients before surgery and anaesthesia [245]. Increasing numbers of “fast-track” operations and shorter hospital stays highlight the need to collect mortality data after patients are discharged from hospital [245, 643, 644]. In-hospital death rates are subject to variation in hospital discharge practices, systems efficiency and length of stay [391, 419]. Local circumstances, differences in “do not resuscitate” policies, and the availability of social support all affect whether dying patients remain in hospital, are transferred to other care facilities or are discharged to the care of relatives at home [184, 391]. Gathering information about postoperative mortality at discrete intervals post-discharge eliminates the confounding effects of variation in discharge procedures.

4.3.5 Measurement of preoperative health state
Perioperative mortality is associated with preoperative comorbid disease, poor chronic health status as represented by the ASA score [645] and advanced age [37, 87, 112, 125-127, 646, 647]. Several studies stress the importance of adjusting for casemix and severity of disease when using RCD to compare patient outcomes [648-654]. Yet, RCD about inpatient episodes do not provide an indication of the severity of illness present at the time of admission and it is difficult to separate pre-existing conditions from complications of treatment [391, 421, 655]. Rather than attempting to use the ICD [413]-encoded diagnoses [414], we used ASA score and age as measures of pre-existing illness. These data are widely reported in anaesthesia studies [187], are captured at the point of care by clinicians and administrators, and should therefore be readily available to anaesthetists.

4.3.6 Measurement of intervention
Major and urgent surgeries are associated with increased risk of postoperative mortality [139, 140, 162, 656]. Mortality rates are often higher for emergency surgeries compared with those for similar procedures that are performed electively [657]. Patients undergoing emergency surgery tend to be at higher risk of serious illness compared with those who undergo similar surgery electively [169]. Although AAC is responsible for the assessment of patients
undergoing elective and not emergency surgery, we also considered mortality rates for emergency surgeries to maintain face validity of the dataset.

We were unable to obtain a measure of the magnitude of surgery within the existing HISs. The ICD (Tenth Revision), Australian Modification (ICD-10-AM) and the Australian Classification of Health Interventions (ACHI) are used in Australian and NZ hospitals to record all surgical procedures performed at public and private hospitals across NZ [658]. The classification is structured by body system, site and intervention type and contains more than 6,000 unique, seven-digit codes. The distinct list of codes is contained in the PIMS and the appropriate code/s are selected by the theatre nurses whilst in the operating room. However, these procedure codes do not include a measure of how invasive or complex a surgical procedure is and there did not appear to be a standard classification available in the literature either. Studies have previously used the BUPA schedule in which procedures are rated by complexity on an eight-point scale from “minor” to “complex major” [36, 156]. Discrepancies in the schedule are apparent because its purpose is to guide reimbursement of fees in private practice [157]. Other risk assessment tools arbitrarily define operative risk. Guidelines for the risk of several procedures are provided, but not all procedures are listed and doctors are advised to select the closest [176]. Definitions of major and minor surgery remain broad in their scope and subjective in their interpretation [158]. Email communication with staff in the clinical coding department, surgeons and anaesthetists all reaffirmed the absence of a universal classification for surgery-specific risk. These communications suggested that ASA was used as a proxy.

We acknowledged this limitation and set out to define a measure of operative risk based on clinical judgement. I obtained the distinct list of ACHI procedure codes from the PIMS and provided this list to Dr Campbell to assign a measure of the magnitude of surgery. We agreed on a three-point ordinal scale from 1 (low risk) through to 3 (high risk). Dr Campbell assigned a score to each procedure in the list using Microsoft Excel 2003 and this list was subsequently loaded into the prototype to serve as a reference dataset. The reference dataset was later joined to the ACHI procedure codes assigned to each patient’s intraoperative record to derive a measure of surgical risk. We agreed that if more than one procedure code was assigned during surgery, the entire surgery would be classified according to the procedure code with the highest operative risk score.

4.3.7 Background rate of attrition
The risk of postoperative death is a combination of the risk specific to the surgery, the risk related to the patient’s current medical condition/s, and the background risk of attrition, which
is independent of the surgery or the indications for it [657]. The underlying risk of death is an important consideration if mortality data are collected over long periods of time. Competing causes of death, including the ongoing rates of death associated with pre-existing disease, may be significant in older populations and could potentially dilute or overwhelm any observed effect associated with surgery [45, 244, 657, 659, 660]. Mortality after surgery is sometimes compared with mortality in the general population to estimate the additional perioperative risk of the procedure. Using life tables, patients are compared with those in the general population of the same age and gender during the same calendar year as the year of surgery [661]. We used this approach to complement estimates of mortality and presented age, sex and calendar-time adjusted life table figures for the NZ resident population. However, this definition of attrition is inherently limited. Patients who choose to pursue non-operative management of their condition retain the risk associated with their “surgical disease” as well as the risk associated with factors such as age and comorbidity that predispose them to attrition. Therefore, patients who do not undergo surgery will have higher attrition compared with estimates from the life tables, making it difficult to estimate “excess” risk of dying.

4.3.8 Specification of the numerator and denominator data

We decided to extract demographic and clinical data across the PIMS, PAS and AIMS for patients who underwent non-cardiac surgery at Auckland City Hospital from November 2002 to October 2012. The denominator included all patients with an electronic intraoperative record in the PIMS, who underwent general, urological, vascular, orthopaedic, neuro-, gynaecological or otorhinolaryngological surgery at Auckland City Hospital between November 2002 and October 2012. Patients were ASA1–4 +/- E and aged 16 years or older at the time of surgery. We excluded surgeries performed by cardiothoracic, transplant, radiology and maternity services because patients admitted under these services commonly receive care within separate dedicated pathways [162]. Day-stay procedures were excluded because the risk of perioperative mortality in the outpatient population is low [151]. Records for patients with an ASA score of 5 or 6 were excluded because, by definition, these patients would not be seen at AAC. Records for patients aged less than 16 years at the time of surgery were excluded because these patients are more commonly cared for by paediatric anaesthetists at Starship Children’s Hospital.

We also restricted the dataset to patients with a valid, primary National Health Index (NHI) number. The NHI was established in 1993 to uniquely identify recipients of healthcare services in NZ [5]. Approximately 95% of the NZ population have a valid NHI [662]. Because of its importance, the NHI contains a built-in validation routine that is designed to
minimise data entry errors [663]. The NHI number is a unique alphanumeric identifier consisting of 7 characters, with 3 alphabetical characters followed by 4 numeric characters. The seventh character is a check digit based on modulus 11 [663]. We incorporated the NHI validation routine to exclude incorrectly formatted NHIs [663]. We also excluded secondary NHIs to minimise the impact of re-registration on the reliability of the dataset. When multiple NHI records are identified for the same patient, these records are linked. From this point onwards, one of the NHIs will be deemed as the primary (or master), and the others become secondary NHIs [664]. For the analysis of RCD relating to a unique patient, the Ministry of Health recommends that the primary NHI number should be used [664].

We were careful to exclude surgeries that were cancelled and those surgeries that did not include a valid ACHI procedure code. We knew from our work with the PIMS user screens, conversations with theatre staff and functional application support analysts, and documentation of the business rules for the PIMS, that timestamps were entered differently for some cancellations such as those that occur on the day of surgery. For example, business rules for the PIMS required that the “Into Theatre” and “Out of Theatre” fields should be completed for patients whose elective surgery had been cancelled, even if the patient had been waiting some time in ORDA/pre-op to go through to theatre or had already entered the theatre when their procedure was cancelled. To retain the timestamps that had already been entered into the “Sent for” and “Arrived” fields under the pre-op tab in the PIMS and still be able to close off the record, staff were required to complete the “In Theatre”, “Out of Theatre” and “Outcome” fields. The “Into Theatre” and “Out of Theatre” timestamps in the PIMS record were either identical or were configured to differ by one minute, and the “Outcome” of the surgery was set to the option “Cancelled – No procedure done” (see Figure 33).
Figure 33. A day-of-surgery cancellation represented in the PIMS.

A small number of cancelled surgeries conformed to this rule but the outcome was not selected as “Cancelled – No procedure done”. These records were excluded. Finally, conversations with theatre staff revealed that an intraoperative record with no ACHI procedure codes assigned was also likely to indicate a surgery that was not performed. These records were also excluded.

In summary, our work in the information modelling quadrant sought to construct physical data models of the HIS, to select attributes from these systems for inclusion, and, more generally, to dig into the deeper layers of the data to learn about its structure, content, relationships and derivation rules through conversations with frontline and back-room staff. Through this work we were able to verify that the necessary data existed (or could be created) and to assess that the data was in a useable state. This work resulted in a high-level source to target (S2T) map, which is presented in Table 25.
Table 25. Description of high-level source to target map and the rationale for inclusion of source system attributes.

<table>
<thead>
<tr>
<th>Target attribute</th>
<th>Source system attribute</th>
<th>Source system</th>
<th>Rationale for inclusion</th>
<th>Excluded records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative health state</td>
<td>Unique patient identifier</td>
<td>NHI number</td>
<td>PAS</td>
<td>Required to uniquely identify patient records</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>Date of birth</td>
<td></td>
<td>Combination of ASA, and age provides a good estimate of mortality across different patient groups [37, 171].</td>
</tr>
<tr>
<td></td>
<td>ASA</td>
<td>ASA</td>
<td>PIMS</td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>Unique surgery identifier</td>
<td>Theatre schedule reference number</td>
<td>PIMS</td>
<td>Required to uniquely identify an instance of surgery</td>
</tr>
<tr>
<td></td>
<td>Surgical risk</td>
<td>ACHI procedure code</td>
<td>PIMS</td>
<td>Major surgery is associated with increased risk of an adverse outcome [139, 140, 162].</td>
</tr>
<tr>
<td></td>
<td>Operative risk score per ACHI procedure code</td>
<td>Reference data coded by Dr Campbell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of surgery</td>
<td>Surgical service responsible for performing the surgery</td>
<td>PIMS</td>
<td>Provides the basis on which to combine multiple operations together to produce an aggregate mortality rate [665].</td>
</tr>
<tr>
<td></td>
<td>Urgency</td>
<td>Acuity</td>
<td></td>
<td>Mortality rates are often higher for emergency surgeries compared with those for similar operations that are performed electively [657].</td>
</tr>
<tr>
<td></td>
<td>Whether the surgery occurred</td>
<td>Outcome; Surgery start time; Surgery end time; Cancelled date and time</td>
<td></td>
<td>Provides the basis on which to exclude surgeries that were never performed</td>
</tr>
<tr>
<td>Postoperative outcome</td>
<td>Death at 30 days and 1 year after surgery</td>
<td>Date of death</td>
<td>PAS</td>
<td>Widely reported, unambiguous event with readily available data [54, 421, 620, 621]. Temporal measure avoids confounding due to variation in discharge procedures [391, 419]. Death beyond 30 days can be used to provide risk information to patients before surgery [245].</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date of surgery</td>
<td>PIMS</td>
<td></td>
</tr>
<tr>
<td>Outcome in general population</td>
<td>Sex</td>
<td>Sex</td>
<td>NZ life tables</td>
<td>Conventional approach to specifying background mortality: patients are compared with those in the general population of the same age and gender during the same calendar year as the year of surgery [661].</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>Date of birth</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year of surgery</td>
<td>Date of surgery</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Although the bulk of the work in the information modelling quadrant focused on source system exploration, a small proportion was also carried out for the BI prototype itself. As part of this work, I developed class and deployment diagrams. For example, a deployment diagram was constructed to detail what hardware and software components would need to exist and how the different pieces would be connected. As this was a BI prototype and not an application for transactional support, there was limited functionality to implement and so behaviour diagrams were considered to be unnecessary.

### 4.3.9 Information system modelling in the context of the BI prototype

The aim of the information modelling quadrant in Multiview2 is to develop a representation of the IS using object-oriented analysis and design [4]. To this end, Unified Modeling Language (UML) [666] is typically used to specify ISD requirements from a technical rationality perspective [534]. UML is used to visualise, construct and document the artefacts of a software system that is built using object-oriented development processes [666]. Although UML is a well-known formalism in traditional software development, the standard has not been widely adopted in BI. There appear to be two key reasons for this. First, UML is a general-purpose language that is not specifically designed for the BI context. According to Luján-Mora [667], UML does not capture attributes and their interrelations as first-class modelling elements. Instead, the standard views attributes as second-class, weak entities, with a descriptive role that would likely be accessed via notes in the UML model [667]. Second, UML tends to focus primarily on static and dynamic ontologies derived from object-oriented notations, but not the intentional or social ontologies that encompass actors and their wants and desires, social settings and organisational structures, networks of alliances and interdependencies that are requisite for business reasoning [668] [668, 669]. Intentional and social ontologies are important because BI is highly contextualised [670-673]. To address the shortcomings of UML in the context of BI, several authors have proposed extensions to UML for data warehouse development [674-676], but again these are not widely adopted by practitioners.

Although information system modelling is intended to provide a technical representation of the IS under development, work in this quadrant could be seen to encompass modelling of both the source and target systems. Throughout the ISD, information system modelling focused on source system exploration and data profiling to generate a technical representation of the source systems. Activity in this quadrant afforded me an opportunity to dig into the deeper layers of the data, to learn about its structure, content, relationships, and derivation rules. It provided me with an opportunity to verify that the data existed (or could be created,
as was the case for operative risk) and to gauge whether the data was in a useable state. Through informal conversations with frontline and back-room staff, first hand observation and limited documentation from the source systems under investigation, I was able to develop an understanding of the business rules, system work-arounds and idiosyncrasies that shaped data capture. Armed with a query tool and my construction of the source system data model, I was able to develop a good understanding of the nature of the source system data required for the BI prototype. As I worked my way through the source systems, starting with individual fields and ending with whole suites of tables, I was also able to develop an understanding of the work that would be required to convert the data into the dimensional model form [446] (if we were indeed building a star schema in a data warehouse and not merely prototype).

Based on our experiences, information system modelling in the Multiview2 methods matrix can be thought of as data modelling. In the context of software development, this activity is concerned with developing a representation of the to-be information system using UML. In comparison, our goal in developing the BI prototype was to reconstruct a physical data model of the source systems that would feed the BI prototype. Had we been developing a fully fledged star schema, we would also have constructed a representation of the BI prototype in the form of a dimensional model. As this was not the case, we created a basic S2T map to represent the BI prototype in technical terms. It is worth mentioning that, although these models are not strictly object-oriented, they are not entirely detached from the Multiview framework. Similar models, namely entity relationship models and data flow diagrams, featured prominently in the original Multiview methods of the information modelling quadrant before the object-oriented programming paradigm became popular [4]. Although neither physical data models of source systems nor dimensional models make use of the UML standard, they both provide a technical representation of the system which is, by definition, the aim of the information modelling quadrant.

4.4 Software development

The project continued with the evolutionary process of software development for the BI prototype. Traditionally, this activity has been the focus of the computer scientist and encompasses the design and construction of software, hardware, and communications technologies [534]. Work in this quadrant extended to both the internal design of the software comprising of methods, functions and classes in object-oriented programming [556, 557], and the external design of the human-computer interface [558]. As with the preceding subsections, the activities that occurred in the software development quadrant are described first, after
which the stereotypical activities in the software development quadrant are contrasted with what actually occurred in practice.

4.4.1 Software development for the BI prototype

The physical requirements of the implementation for the BI prototype were clear. We needed a process to extract, transform and load data into a database; a web application to display the data in this database to users; and technology to link the two components together. The choice of technology was driven by a mixture of the technologies available with limited financial resources, a preference to work with the Microsoft technology stack, and previous development experience of the team. The overall architecture is shown in Figure 34.

Figure 34. Architecture diagram for the BI prototype alongside the perioperative care pathway for elective surgery.

Note: JSON: JavaScript Object Notation; HTML: Hypertext Markup Language; SQL: Structured Query Language.

In keeping with the learnings from the information system modelling quadrant, I extracted the required data using SQL and deterministic data linkage of shared internal identifiers to join records for the same patient across the PIMS and PAS. I then applied the necessary transformations, including calculating age at time of surgery from the date of birth and date of surgery, and loaded the data into a data mart in a Microsoft SQL Server database. As part of
this process, I corrected for the possibility of multiple surgeries being performed during the study period on the same patient. This was necessary to ensure that death within 30 days or 1 year of surgery was a dichotomous “yes/no” value, regardless of the number of times the patient returned to have surgery within the post-discharge time period of the index surgery.

I used summarisation methods to compute summary information, which provided a concise description of the characteristics of the data. In keeping with the literature, I grouped surgical procedures by the surgical service under which they were performed. Owing to small sample sizes, procedure specific mortality rates are of limited use at individual hospitals [677]. To improve outcomes measurement in non-cardiac surgery, studies have suggested that similar procedures should be grouped together to produce an aggregate mortality rate [665]. The rationale for this recommendation is that significant relationships between outcomes for different surgical procedures are likely to exist because many surgeries depend on the same hospital-level resources, staffing and processes of care [678-680]. For example, strong correlations between mortality rates for different procedures in cardiothoracic and paediatric surgery, and across different surgical specialties for high-risk procedures, have been reported [680-682]. Accordingly, surgical procedures were grouped by the surgical service under which they were performed prior during summarisation. Patient records were also categorised into five arbitrary age bands: 16–69, 70–79, 80–89 or 90 and over. Records for ASA 1 and 2 patients were combined into one category – “ASA 1 and 2” – because postoperative mortality in this group of patients is known to be relatively infrequent [32, 632].

The BI prototype tabulated mortality as death within 30 days or 1 year of surgery for each combination of surgical service, urgency, ASA score, age band and surgical risk. In addition, 95% binomial Wald-type confidence intervals were calculated to indicate the precision of the estimates. I developed the graphical user interface in liaison with the Dr Campbell and with technical mentorship from the external software developer. The estimates were displayed in a web browser via a web application built on the Microsoft ASP.NET MVC framework. User interface behaviour was developed in JavaScript. Requests for data were processed server-side and the resulting estimates were returned in a JavaScript Object Notation data structure. The web application was deployed to the hospital intranet and was hosted using Microsoft Internet Information Services. A hyperlink to the web application was added to the departmental intranet page to allow interested anaesthetists and physicians to provide informal feedback on our work. Using this link, anaesthetists were able to access the website and select patient-specific and surgery-specific parameters to obtain estimates of 30-day and 1-year mortality displayed according to ASA score and age band for patients who underwent non-
cardiac surgery at Auckland City Hospital from 2002 to 2012. (Figure 35).

![Mortality Indicator](image)

**Figure 35.** Web application showing perioperative mortality by ASA score, urgency, age, surgical service and severity.

### 4.4.2 Software development in the context of the BI prototype

Software development seeks to construct systems that fulfil the client’s requirements [598]. In the context of Multiview2, functions and data in structured methods or classes and a human-computer interface are created as part of this activity [534]. In the context of the BI prototype, I developed functions and procedures for data retrieval and transformation. Predicates were used in the search condition of “WHERE” clauses in the SQL statements to exclude unnecessary rows based on the learnings specified in the information modelling quadrant. Other transformations were applied, for example, deriving the patient’s age at the time of surgery before persisting records in the data mart. Although, we developed a web application to present the database query results, we argue that software development in the Multiview2 methods matrix is better thought of as technical development. This reflects the data-centric, decision-support focus of BI development rather than the transaction-centric, workflow-support focus of software application development.
4.5 Feedback on the BI prototype

Throughout the ISD, Dr Campbell and I received feedback about the utility, novelty and understandability of the prototype. Dr Campbell presented the prototype at the weekly departmental Clinical Forum Meeting in late 2011 and again to a wider audience of anaesthetists from other departments at the Annual Anaesthetists Research Meeting in August 2012. Presentation slides were available to all attendees to ensure that the learnings from our work were organised and accessible. We also submitted a poster presentation for the Auckland DHB celebration week in November 2013. Throughout the entire process, we received informal feedback by way of “corridor conversations” and email correspondence to Dr Campbell and myself. The feedback was largely positive:

*I’ve had a look at your Mortality Indicator . . . This is spectacularly good. The user interface is clean and responsive. A useful clinical adjunct.* (Email communication from physician to Dr Campbell and myself, September 2011)

*I used this twice on Monday with inpatient assessments and it really helped in the discussions.* (Email communication from anaesthetist to Dr Campbell and myself, October 2011)

*Certainly with Doug’s database thing and your database thing, then actually that’s potentially really useful.* (Face-to-face conversation between clinic anaesthetist and myself, June 2012)

We also received requests for changes that required a brief return to the software development quadrant. For example, the initial prototype required the anaesthetist to select a surgery as being either “high”, “intermediate” or “low” surgical risk. We received a change request to make this field optional on the user interface. The initial prototype also applied colour coding to arbitrary mortality bands which some anaesthetists found confusing. After consultation with Dr Campbell, I removed the colour codes and designated surgical risk as an optional field. We also received requests to include 30-day and 3-month mortality because the initial prototype only included 1-year mortality:

* . . . Have you thought of doing a 30-day mortality calculator? I think this would be very educational for us all . . .* (Email communication from physician to myself, Sept 2011)

* . . . having a 3 month mortality between the life table and the predicted 1 year would really help me pitch the message to the patients* (Email communication from anaesthetist to Dr Campbell and myself, October 2011)

In response, Dr Campbell requested data for 1-month, 3-month and 1-year mortality, and, based on these figures, made the decision to present 1-month data in tandem with 1-year mortality. I subsequently completed the development required for this change and Dr
Campbell fed back the outcome of our work to the anaesthetists who had enquired. Other change requests that would result in further “splitting” of the dataset were not actioned and this decision was fed back to requestors. For example, we received a request to further summarise the data for diabetic and non-diabetic patients. We declined to make the change and stressed that doing so would lead to further widening of the confidence intervals and decreased clinical utility of the prototype.

4.6 Discussion

The Multiview2 framework was used as a sensitising device to enquire into the characteristics of BI development and, more specifically, to explain how a BI development methodology emerged. This study was undertaken to address the first objective of this thesis: to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in healthcare. This chapter has focused on the work we undertook in the organisational analysis, information modelling and software development quadrants of the framework. The study identified three stereotypical roles in BI development, namely orientating, discovering and presenting. Three outcomes of BI development were also discovered: a plan of action as a result of organisational analysis; S2T map and physical data models of source systems, and dimensional models of the target system from data modelling activities; and a BI artefact from technical development. Consistent with Vidgen’s approach [533], the methods matrix has been annotated with both the stereotypical roles and their outcomes, and the information modelling and software development quadrants have been updated to data modelling and technical development respectively. The data modelling quadrant is given the appearance of being divided into two parts to emphasise the need to focus on both the as-is source systems and the to-be BI artefact. After revising the framework, Multiview2 was thought to be even more appropriate for BI development. The revised Multiview2 framework is shown in Figure 36.
The Multiview2 approach to systems development [534] (top) compared with the elaborated Multiview2 framework for BI development after PAR cycle 1 (bottom).

The strength of this study lies in its use of PAR to gain valuable firsthand experience of the practice of BI development. Although there is considerable practitioner wisdom in the form of two competing paradigms for building a data warehouse/BI system – the Kimball lifecycle [446] and Inmon approach [683] – there are few, if any, academic studies that have
systematically and rigorously investigated BI development methodologies. The revised framework provides a conceptualisation of BI development which is grounded in data that were intentionally sought and purposefully collected, rather than anecdotal evidence from practitioners [684], hunches or preferences.

A corollary of this point is that the process of explaining the emergent BI development methodology is made more scientific. Multiview2 is neither prescriptive nor exacting [537], so the methodology is able to support the development of a situated BI solution to solve a local problem. This is especially important because BI, to be valuable, needs to be heavily contextualised to the specific organisational context; and to inform and be informed by business users and their local operational knowledge [670-673]. Additionally, each and every application of Multiview represents an exploration in ISD throughout which Multiview is interpreted [537]. By actively reflecting on what a practitioner is doing, it becomes easier to see what a practitioner is not doing. Multiview raises questions about aspects of a BI project that do not explicitly fall within its gamut [598], such as formal unit testing and training, which were undertaken informally during this project.

The strengths of this study are also tempered by its shortcomings. The most significant of these relates to the type of project that was developed and the context in which development occurred. The study sought to develop a prototype, and not a fully functional BI artefact. In keeping with this decision, a sufficiently sized data warehouse build was not required; there was no official rollout, change management or training; and no mandate for the prototype to be used as part of the anaesthetic assessment. These characteristics of the study raise some questions about the generalisability of findings to other contexts. Larger, more formalised BI projects are likely to require some, if not all of these aspects. However, it is likely that the revised framework is sufficiently flexible to accommodate these activities. In their study of a major, multinational programme of enterprise resource planning (ERP) implementation, Kawalek et al. [598] used the Multiview framework as a diagnostic device to enquire into the characteristics of the ERP implementation methods used at different case study sites. In doing so, the authors demonstrated the potential for Multiview to cater for diverse activities such as integration and user acceptance testing, training, documentation, and change management and help desk requests that were logged after go-live. Additionally, their research provided evidence of the value of the Multiview framework outside of the subspecialties of desktop [4] or web application development [533].

Use of the Multiview framework has not been widespread in the IS/IT literature and studies are largely confined to those of the authors of Multiview [4]. Among the most recent of these,
Vidgen [533] investigated the appropriateness of Multiview to web-based ISD on a 2-year e-commerce development project. The web ISD methodology (WISDM) emerged from the application of Multiview in this context. A finding common to both Vidgen’s study and the development of the BI prototype was that, given the reading of the respective situations, SSM was not perceived as being meaningful for the organisational analysis. Case studies that employed the Multiview framework in its original form appear to be the only examples of the use of SSM methods within the framework. This observation suggests that the answer to the question of whether the framework supports the use of SSM may lie in the reasons for the revision of Multiview to Multiview2. In its original form, Multiview omitted the software construction, implementation and maintenance activities of the systems development life cycle, implying that these ought to be dealt with outside of the methodology. Excluding these activities seemed to suggest that Multiview was predominantly concerned with the analysis and design activities of ISD [4], so the framework appeared to imply a waterfall approach, which calls for the completion of analysis and design before development can begin [534]. Vidgen’s study and the development of the BI prototype are similar in the sense that both ISD efforts resulted in one or more prototypes. It is possible that the absence of SSM from both emergent methodologies reflects the mainstream adoption of iterative, incremental and interactive approaches to development such as prototyping and agile software development principles [685], both in application development [686] and now in BI [687].

Although studies on BI development methodologies in the literature are limited, examination of factors that are deemed to affect BI success may prove fruitful. According to the authors of Multiview, a successful ISD will likely need a mix of all of the aspects described in the methods matrix, though in what quantities and at what times remains to be seen [4, 534]. It follows that successful BI development projects are likely to need a mix of organisational analysis, data modelling, sociotechnical analysis and technical development. There appears to be some support for this conceptualisation. Wixom and Watson [684] surveyed data warehousing managers and suppliers about the factors affecting data warehouse success. Statistical analysis revealed that diverse, unstandardised source systems and poor development technology lead to technical issues that development teams must overcome. BI projects are inherently risky and often subject to failure [688, 689]. Practitioner wisdom holds that the BI team should explore and profile source systems with a view to making a “Go-No Go” decision early on for the project as a whole [690]. Multiview2 is explicit in its requirement for data modelling, which in keeping with practitioner wisdom, involves identifying potential source systems and learning about their structure, content, relationships and derivation rules [446]. It is pertinent that these activities are represented by the data
modelling quadrant in the methods matrix, not only to make it clear that this activity is central to the practice of BI development, but also to remind practitioners that early identification of poor data quality can lead the development team to technical implementation success.

This study has a clear implication for practitioners: that frontline and back-room learning are equally required to disentangle information from the context in which it is produced. Berg [691, 692] argues the point that medical data do not constitute some repository which can easily be tapped into, so their use is not simply a matter of selecting which attributes to transport and where. On this basis, he claims that active, interpretive work is required to translate healthcare data for secondary use. Yet his works are largely silent on how one goes about doing this translation. In his writings of the contextual nature of medical information [692], he poses the question of who is responsible for performing this translation work. In posing this question, he perhaps signalled his belief that answering the question of “who” will go some ways to understanding the “how”. Practitioner wisdom, on the other hand, holds that engagement with the business is crucial for requirements gathering and source system discovery [446]. However, these writings are not conceptual in their understanding of the need for this engagement. Practitioner wisdom speaks to the need for user participation and motivation to ensure that the right functionality is delivered, and data quality issues are addressed early on in the piece [446]. Unlike Berg, these writings do not position business engagement as that which is needed to disentangle information from the context in which it is produced.

It follows that unique and sometimes tacit or inarticulable knowledge [693, 694] is required to accomplish this work. To the uninitiated analyst or developer, data on a BI project may be fraught with error, inconsistency and uncertainty – surgery may only have lasted for a minute; nurse-entered and anaesthetist-entered ASA scores are discordant; or surgery may have occurred as scheduled but no procedures were performed. Consistent with practitioner wisdom, frontline conversations with business users at multiple posts as well as back-room approaches such as unaided browsing and computer-aided techniques are both necessary for understanding the idiosyncrasies that the analyst or developer is likely to encounter. Yet the true value of this observation is manifest in light of Berg’s writings: when the practitioner’s activities, both frontline and back-room, are viewed as “work”, we come to appreciate that much sense-making – an important and valuable skill – is needed to implement structures that derive from intimate, empirical knowledge of users’ processes and practices [691], as well as from abstracted models. Perhaps in posing the question of “who” should do this work, Berg
conveyed more about the complexities of work, which is imbued with tacit knowledge, for the betterment of our discipline than he himself was aware.

This research has uncovered new insights into the practice of BI development (evident in the revised Multiview2 framework), but important questions remain unanswered and further work is needed to address these. First, Multiview2 does not speak to several factors which are generally considered to be present for successful ISD. Wixom and Watson’s [684] analysis also found that management support and resources help to address organisational issues and a highly skilled project team increases the likelihood of achieving data warehousing success. Further research is needed to determine the impact (if any) of the calibre of the team members or the presence (or lack of) management buy-in on the use of Multiview2 in practice. More generally, studies are needed to compare the Multiview2 framework with practitioner-based methodologies, such as the Kimball life cycle [446]. Subjecting practitioner-based methodologies to comparative research may offer an opportunity for practitioners and researchers to collaborate and, in doing so, ensure the success of these IT undertakings. Lastly, although Multiview2 has been shown to be valuable in different contexts, the fact remains that the development of new ICTs in healthcare is an especially complex and dynamic sociotechnical process [496]. The healthcare environment, in particular, is often characterised by “missing information, shifting goals and a great deal of uncertainty” [570, p.142] and ambiguity. This makes traditional approaches to systems development difficult to successfully apply in this context [570]. Successful creation of IT in healthcare requires a flexible, iterative and incremental approach to development, one that gives due emphasis to the need for continuous learning, experimentation and improvisation [496]. Multiview, as a methodology that incorporates many of these tenets, could provide valuable information about the development of ICTs in what is widely considered to be an otherwise challenging space.

4.7 Conclusion

In this chapter, I presented the findings from the first PAR cycle, which resulted in the development of a BI prototype to present anaesthetists with information about perioperative mortality at the point of care. Research in this cycle sought to address the first objective of this thesis: to investigate the appropriateness of the Multiview2 methodology to inform BI the development of a BI prototype in the healthcare sector. With this objective in mind, I presented the work that Dr Campbell and I undertook in the organisational analysis, information modelling and software development quadrants of the Multiview2 methodology. The indicative and stereotypical methods of Multiview2 were contrasted with what actually occurred in practice for each of these quadrants. This exercise led to the revised Multiview2
framework which is thought to be increasingly appropriate for BI development. Yet, human considerations are equally important as technical ones, and therefore our work at this point was considered incomplete. To honour the requirement for symmetry between social and technical factors [566], we went on to conduct detailed work in the sociotechnical analysis quadrant – the fourth and final quadrant in the Multiview framework. The contribution of this work to the second revision of Multiview2 for BI development is described in the chapter that follows.
Chapter 5: Exploring the work of risk communication at AAC

5.1 Introduction

In Chapter 4, I presented the findings from the first PAR cycle, which resulted in the development of a BI prototype to present anaesthetists with information about perioperative mortality at the point of care. In this chapter, the findings from the second PAR cycle are presented (Figure 37). Research in this cycle sought to address the first and second objectives of this thesis. The first objective was to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in the healthcare sector. The second objective was to explore how the work of risk communication is accomplished at AAC.

Figure 37. Data collection and analysis for PAR cycle 2.
In the previous chapter, the methods used in the development of the BI prototype were presented using three of the four quadrants of the Multiview2 methods matrix, namely the organisational analysis, information modelling and software development quadrants (Figure 38). In this chapter, the research is presented using the fourth and final quadrant of the methods matrix – sociotechnical analysis.

![Figure 38. The sociotechnical analysis quadrant of the Multiview2 methods matrix.]

To address these two objectives, the chapter is structured as follows. First, I provide a review of relevant background literature and my reflections on the first PAR cycle to frame the theoretical and practical and underpinnings of this chapter. This section is followed by a brief overview of the data collection and analysis methods that were employed. Next, I describe the key findings. First, the findings from a series of qualitative interviews with specialist anaesthetists are described. Second, the indicative and stereotypical methods of the sociotechnical analysis quadrant are contrasted with what actually occurred in practice to gain further insight into the appropriateness of Multiview2 for BI development. Next, the respective findings are contrasted with existing literature in the discussion section. Finally, the chapter concludes with a summary of the findings from the work that was undertaken in this quadrant.

### 5.2 Background

The background section of this chapter covers first the reflections from the first PAR cycle and then the theoretical underpinnings in the literature.
5.2.1 Reflections from the first PAR cycle
The Multiview2 framework was used throughout the thesis to inform the emergence of a local, situation-specific ISD methodology that resulted from the engagement of Dr Campbell, myself and, at times, the wider department with the problem situation. Throughout the first PAR cycle, concerns about feasibility and data quality had made it necessary to focus on the objective aspects of the ISD, leaving some of the more subjective aspects at the periphery. Using Avison and colleagues’ [534] metaphor of the film camera, we had necessarily focused in on two particular quadrants in detail – information modelling and software development – at the expense of losing some of the context. After the initial deployment, I came to realise what little I knew of how anaesthetists go about assessing and communicating risk to their patients as part of the shared decision-making that occurs at AAC. Dr Campbell also conceded that he was not overly familiar with his colleagues’ practices in this area. We felt that a working knowledge of the information sources anaesthetists weave into their conversations about risk, how they present risk to their patients, and what metaphors and heuristics, words and numbers they use in their conversations with patients was lacking. A description of the existing work system would also likely aid in any future development. Hence, the second PAR cycle represented our commitment to handle the whole question of how best to introduce technology into people’s work, which is laden with assumptions regarding how people go about their work and, more generally, how organisations function [4, 555]. In opening out the ISD to conduct sociotechnical analysis, our work broadened to include a general concern with “how work actually gets done” [555, p.124]; that is, how anaesthetists accomplish the work of risk assessment and communication at AAC.

5.2.2 Theoretical underpinnings
In Chapter 2, the literature review, the concepts of risk, risk assessment and, briefly, risk communication were described. The relationship between these three aspects at the anaesthetic assessment was shown in Figure 10 and is reproduced in Figure 39 (below) for clarity. The subject of risk communication is dealt with in more detail in this chapter. Risk communication is the reciprocal exchange of information and opinion about risk, which leads to better understanding and improved decisions about the management of patients’ clinical care [44, 695]. However, the communication of risks in theory and practice is not as straightforward as this definition might lead one to believe [696]. Many different dimensions and uncertainties must be taken into consideration including, but not limited to, the proposed surgery; the patient’s medical condition, their desire for information [697-700]; and his or her subjective perceptions, values and beliefs [342, 701-704]. Effective risk communication is required to achieve shared decision-making and greater evidence-based patient choice [705].
Disclosure of material risk is also part of the process of informed consent for anaesthesia [246]. Yet studies on risk communication in anaesthesia are few and rarely explore the nature of the work – those circumstantial and interactional influences on how risk is assessed and communicated – especially in regard to how patients and healthcare professionals involve each other in such communication [706-710]. The purpose of this PAR cycle was to address the second objective of the thesis: to explore how anaesthetists accomplish the work of risk assessment and communication at AAC.

Figure 39. Risk assessment and communication during the preoperative anaesthetic assessment.

The literature on work practices underpinned our research in this cycle. According to Sachs [711, p.125], the “work practices” view conceptualises work in terms of “problem-solving practices, communities and social interactions to assess the nature of social organization and reasoning in real-world contexts of how work actually gets done”. This view of work supposes that the collection of activities, relationships, communication practices and coordination necessary to realise business functions are complex and continually mediated by employees and employers alike. Dealing with whole activities as opposed to particular tasks leads to a broader conception of work that pays attention to how employees communicate, reason about problems, forge alliances, and learn as a means of getting their work done [555]. Through this lens, everyday work practices are analysed to reveal the ways in which working people accomplish work in actuality and, in doing so, make the business function.
In the context of healthcare more specifically, the management of the patient’s illness trajectory is at the centre of the work of all healthcare professionals [712]. Strauss and Berg, whose texts on the subject of medical sociology continue to be major works of reference today, describe trajectory management as a collective, collaborative and inherently social enterprise. The shape of the trajectory is the contingent result of the day-to-day decisions and actions taken by individuals from diverse professional and personal backgrounds, often with varying viewpoints about the “facts” and what should be done [713]. A broad range of considerations and concerns come to bear on these interactions. Beyond the immediate medical concerns, trajectories and decisions are “shaped by the social context in which they are made” [713, p.22], not least because healthcare is “people work” [712, p.9]. This point, while axiomatic to the sociologist, is worth affirming because it is central to the character of, and indeed the discourse on, healthcare work. The “product” in this line of work is a living, breathing human being, able to react and so affect the work and also capable of participating in the work itself; to be worked on or over, but also with [712].

Because the product is not homogenous, it follows that different types of work [712], of which there are many, are activated at various times to direct the course of the trajectory. For example, machine work is mobilised to monitor the machines required by the highly technological nature of medical work. Safety work can be seen in the assessment and management of risk requiring preventative monitoring, and rectifying action. At the margins of the discussion, comfort work seeks to minimise physical discomfort and sentimental work seeks to address the more psychological aspects of care. Among the remaining work types not described here, information work deserves mention. This is the constant, integral work of passing information between people and place, before, during and after each work task that permits the trajectory to continue on. Viewed in this way, trajectory management includes “not only the physiological unfolding of a patient’s medical condition, but . . . the total organization of work done over the course as well as the impact of those involved with that work and its organisation” [712, p.8]. Transforming the simple concept of the course of illness into its fuller sociological complexity paints a picture of healthcare work as being interpretive and contingent, complex and emergent all at the same time [626, 714, 715].

5.3 Methods

The methods for this chapter were described earlier in Chapter 3. Briefly, the principal data collection technique employed in this cycle was the qualitative interview. In agreement with Dr Campbell, I conducted 30 semistructured interviews with 29 specialist anaesthetists who were rostered to AAC at least once in the 6-month period prior to conducting the interviews.
Interviews were conducted between May 2012 and September 2012. The purpose of these interviews was to develop an understanding of the “work” of risk assessment and communication and how anaesthetists achieve this work in actuality [555]. The decision to pursue this line of enquiry emerged from a review of the data in the first PAR cycle, and the consequent recognition of how little we knew of this work, reflecting the emergent character of AR. Concepts derived from a literature review on informed consent and risk communication were used to inform the design of the interview instrument (Table 26). Democratic dialogue between Dr Campbell and I refined the instrument to ensure that the relevant areas were canvassed. Briefly, anaesthetists were asked to provide their views on informed consent, describe their approach to risk communication at AAC, and to identify the challenges or other factors that modify their approach to risk communication. All interviews were transcribed verbatim by a professional transcriptionist and were subsequently analysed in keeping with an interpretive and idiographic viewpoint [78] using Braun and Clarke’s [599] approach to thematic analysis.

Table 26. Interview instrument and supporting literature.

<table>
<thead>
<tr>
<th>Interview question</th>
<th>Supporting literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The following statements relating to informed consent. Which is most consistent</td>
<td>[716]; [717]; [718]; [719];</td>
</tr>
<tr>
<td>with your ideas and why?</td>
<td>[720]; [721]</td>
</tr>
<tr>
<td>2. How often do you believe the transparency model is applied in clinical practice?</td>
<td>[722]</td>
</tr>
<tr>
<td>3. What factors influence or may influence your approach to information disclosure?</td>
<td>[723]</td>
</tr>
<tr>
<td>4. Do you think patients and clinicians perceive risk differently? Why?</td>
<td>[724]; [725]; [726]</td>
</tr>
<tr>
<td>5. What factors do you believe influence patients’ perceptions about anaesthesia?</td>
<td>[702]; [703]; [704]</td>
</tr>
<tr>
<td>6. What do you think patients want you to tell them in relation to risk and how do</td>
<td>[727]; [697]; [699]</td>
</tr>
<tr>
<td>you think they want to hear it?</td>
<td></td>
</tr>
<tr>
<td>7. How would you describe your approach to risk communication at the Anaesthetic</td>
<td>[342]; [54]; [696]; [728];</td>
</tr>
<tr>
<td>Assessment Clinic?</td>
<td></td>
</tr>
<tr>
<td>7.1. On average, how long do you spend talking to patients about risk at clinic?</td>
<td></td>
</tr>
<tr>
<td>7.2. Which sources of information do you use to inform your discussions of risk</td>
<td></td>
</tr>
<tr>
<td>at clinic?</td>
<td></td>
</tr>
<tr>
<td>7.3. Which formats do you use to convey risk?</td>
<td></td>
</tr>
<tr>
<td>7.4. Do you talk about absolute risk or relative risk?</td>
<td></td>
</tr>
<tr>
<td>7.5. Over what time period do you quote these risks?</td>
<td></td>
</tr>
<tr>
<td>7.6. What denominators do you use?</td>
<td></td>
</tr>
<tr>
<td>7.7. How do you convey the uncertainty associated with these risk estimates?</td>
<td></td>
</tr>
<tr>
<td>8. Do you face any challenges when communicating risk to patients? If so, what?</td>
<td>[342]</td>
</tr>
<tr>
<td>9. How do you think we can improve risk communication at the Anaesthetic Assessment Clinic?</td>
<td></td>
</tr>
</tbody>
</table>
5.4 Findings

I conducted 30 semi-structured interviews with a total of 29 clinic anaesthetists. Characteristics of the anaesthetists interviewed are presented in Table 27. Seventeen of the anaesthetists (58.62%) were male, the mean number of years practising medicine was 19.86, and the mean number of years practising as a specialist anaesthetist was 10.48. Most anaesthetists worked in both public and private practice (72.41%) and six individuals worked in public practice only (20.69%). Two individuals worked in both public practice and in other non-clinical roles outside of anaesthesia, lecturing at the University of Auckland or as clinical advisor to the Department of Information Management at Auckland DHB.

Table 27. Characteristics of clinic anaesthetists interviewed during PAR cycle 2.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Anaesthetists (N=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>17 (58.62%)</td>
</tr>
<tr>
<td>Female</td>
<td>12 (41.38%)</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
</tr>
<tr>
<td>Public and private practice</td>
<td>21 (72.41%)</td>
</tr>
<tr>
<td>Public practice only</td>
<td>6 (20.69%)</td>
</tr>
<tr>
<td>Public practice and other</td>
<td>2 (6.90%)</td>
</tr>
<tr>
<td>Number of years since completing</td>
<td></td>
</tr>
<tr>
<td>medical degree, mean (SD)</td>
<td>19.86 (6.24)</td>
</tr>
<tr>
<td>Number of years since fellowship</td>
<td></td>
</tr>
<tr>
<td>awarded, mean (SD)</td>
<td>10.48 (7.80)</td>
</tr>
</tbody>
</table>

Thematic analysis of the transcripts revealed three major themes. The themes were related to (1) anaesthetists’ conceptualisation of informed consent and risk communication; (2) the roles, relationships and responsibilities of parties involved in the preadmission process; and (3) communicating the risks, for which anaesthetists appeared to source information, qualify and quantify the risk, and convey uncertainty. These themes are described in the subsections that follow.

5.4.1 Conceptualising the work

Anaesthetists’ conception of risk communication and informed consent could be described as reflexive and patient-centred. Throughout the interviews, anaesthetists described “the infinite spectrum of people” that they see during the course of their everyday work. Interviewees recognised that “every patient is different” both in their desire for information and how they wish to receive it. Whereas some patients may wish to know nothing of the risks that they might face in their upcoming surgery, others wish to know all of the minutiae. On the grounds
of this observation, anaesthetists described their attempts to tailor their commentary “to the patient in front of them” by way of “checking in”.

“Checking in” referred to the anaesthetist’s practice of gauging how much information the patient required and how it could best be delivered. The practice was a reflexive exercise in which the anaesthetist assessed and reassessed how successful their efforts to impart information were, so as to be “led by the patient” in what information they disclosed and how they disclosed it during the anaesthetic assessment. As part of this practice, some anaesthetists prepared patients with a “warning shot”:

... this is what we’re going to talk about, we’re going to go through it all, it’s kind of scary but we have to talk to everybody about it ... we give them a warning shot so that they know what’s coming up is a standard talk.

After this, they asked questions to discover what the patient might want to know. In conjunction with the “paper chase”, the aim of this discovery process was to come to a decision of what information the patient desired to receive and could assimilate, and how the anaesthetist could best deliver this information:

... I tell people immediately that there are [anaesthetic] options, and I look for their reaction. And if they engage me, then I’ll carry on. If they don’t then I’ll kind of pull back.

I’m a big believer [that you should] communicate with them [the patient] in the style that you think they will like. So a young guy who’s quite blokeish ... I’ll lapse into ‘yeah mate, we’ll do this and that’ and we’ll be very boom, boom, boom and talk a bit about rugby. Whereas an elderly lady, I’d be far more gentle and empathetic and ask them about their pets.

Many interviewees asked patients if they had any questions for them, what their surgeon had told them previously and, more generally, what was worrying them most.

Besides direct questioning, checking in appeared to take on more subtle forms. Anaesthetists described their attempts to “read the [patient’s] body language” to determine whether they were giving the right amount of information, when to pause to give the patient a moment to digest information, and when to pull back and try a different tack. “How the patient is looking” was often a feature in their decision-making about the content and delivery of their communications. If a patient appeared to be distressed or frightened, then the anaesthetist might choose to be less explicit about the risks or tone down their explanation, while still maintaining their obligation to inform the patient. Conversely, anaesthetists described scenarios in which patients were clearly engaged in learning about the risks and they would provide detailed explanations accordingly. Checking in helped anaesthetists to be flexible in
their communications and to ensure that they were “prepared to change [their] . . . game slightly” or, if challenged, “to roll with it to a degree” because not every communication device will work for all patients. One anaesthetist commented that the euphemism of sleep, for example, could be misunderstood by a patient who associates the term with having their pet euthanised. Throughout the interviews, the conceptualisation of informed consent and risk communication as being reflexive and patient-centred, and therefore requiring the practice of checking in, was present to some degree in all of the anaesthetists’ descriptions.

All interviewees appeared to view informed consent as a process and a conversation rather than a one-off event in which the anaesthetist imparted information to the patient. Anaesthetists acknowledged the ever-changing picture of the patient throughout the course of treatment. The patient may change their mind about some aspect of treatment, the results of diagnostic tests may become available leading to new understanding of the patient’s condition, or the patient’s condition may progress such that their clinical picture presents differently in the near future. For these reasons, informed consent was seen as a process rather than a point-in-time event. Anaesthetists also subscribed to the idea of informed consent as a conversation that offered “a chance to chat [to the patient]” and an opportunity to help the patient gain a better understanding of the path forward. One anaesthetist elaborated on the idea of informed consent as a conversation, describing it as something of an exercise in trust building. She used the conversation to get to “a point where they’re [the patient is] actually trusting me to look after them”. Consistent with this view, the patient’s signature on the consent form was seen by all anaesthetists as having little value in comparison to the dynamic and interactive process that culminated in the signing of the form.

*When they [the patient] sign the piece of paper I go, “Look, this actual piece of paper means nothing, the signature means nothing. What’s important is that you know I will look after you to the very best of my ability. End of story.”*

Interviewees shared the perception that although informed consent is a legal instrument that lets patients define their own interests [721], the process is not wholly in aid of acquiring permission to administer an anaesthetic. Rather, anaesthetists perceived informed consent as a process of giving and receiving of information about what the options are for a particular patient and what the outcomes of those different options might be and, in doing so, emphasised the need for the patient to have the capacity to understand this information so as to come to a balanced decision. In this regard, two anaesthetists expressed misgivings about the claim by Beauchamp and Childress [716, p.143] that “informed consent is an autonomous authorisation of a medical intervention”. These anaesthetists suggested that this definition imparts a narrow view of the process as a “one-way street” or little more than “getting
permission to do something”. One of these anaesthetists sensed that, by the authors’
definition, the patient is presented with a set of options and then gives the anaesthetist “a go-
no go for launch”. He didn’t think “consent was that process”. While informed consent does
involve the giving of permission, these anaesthetists felt that Beauchamp and Childress’
definition did not reveal an authentic view of informed consent as a dynamic, interactive,
mutually agreed course of action because it lacked the precondition of an informed patient
who had the necessary information to give their authorisation.

Most interviewees also looked on the idea of informed consent as imperfect. Some
anaesthetists described “true” informed consent as a condition that was never fully realised;
something of “a noble aspiration” or “a laudable goal”. There appeared to be two key reasons
for this perception. Firstly – over and above everyday issues of patient comprehension,
education and literacy, time constraints, impaired communication abilities secondary to
hearing loss, confusion or cognitive impairment, language or cultural difficulties – informed
consent was seen as imperfect for the same reasons that it was described as patient-centred: it
required a value judgement about what to disclose to the patient. Some anaesthetists described
a tension surrounding their belief about a “best course” of action, which the patient was not
party to, such as the use of regional over general anaesthesia. Others highlighted tensions
between their obligation to disclose information and the patient’s desire to receive it,
especially among elderly patients:

“I don’t want to know dear, just . . . cut that thing out . . .” You do get that
from time to time . . . [but] I’ve got a minimum disclosure thing that I’m
comfortable with . . . even if the patient says to me I don’t want to know,
they’re going to hear it.

Also noteworthy was one anaesthetist’s account of her struggle to provide the appropriate
information and pitch it at the right level, which sometimes left her feeling that she
unwittingly patronised some patients or assuming that others knew more than they did. This
sentiment was shared by other anaesthetists who seemed to feel uncertain about how often
they “got it right”. Secondly, several anaesthetists attributed the imperfect nature of the
process of informed consent to asymmetry in the knowledge base and experiences of the
doctor and patient. The patient would be unlikely to have “seen it [perioperative care]
multiple times” and along different trajectories, as a practising anaesthetist would have.
Accordingly, all interviewees reported that patients and anaesthetists will understand and
interpret risk differently. Some anaesthetists felt that while informed consent happens on
“some level”, the knowledge and experience gap between patient and anaesthetist led others
to question how “deep” informed consent really goes.
Finally, informed consent was described by several interviewees as an important part of the anaesthetist’s role and was alluded to as being important by several more. Despite this, many anaesthetists did not appear to have a good grasp of their colleagues’ risk communication practices, but did believe that “everyone does it differently”. Indeed, there appeared to be varying degrees of disclosure and transparency. In line with this, a small number of anaesthetists highlighted a lack of education around the topic, as demonstrated by the following excerpt:

*So yes once again this is more education than we’ve probably ever had in informed consent, is your sitting there talking to us . . .*

This belief led three anaesthetists to identify a need for enhanced learning opportunities on the subject, especially for trainee anaesthetists. Their ideas included the possibility of developing a teaching module for informed consent or role-playing consent discussions within the department. To summarise, anaesthetists characterised informed consent and risk communication as a reflexive, albeit imperfect, patient-centred communication process that involves the giving and receiving of information about surgery and anaesthesia, by an anaesthetist and a patient with the capacity to understand this information.

5.4.2 Relationships, roles and responsibilities

The wider preadmission process appeared to be characterised by distributed decision-making, multiple viewpoints and the evolving (and sometimes inconsistent) knowledge bases of all involved. Many authors and events appeared to exert their influence on the course of the preadmission process. Anaesthetists observed that the patient had usually met with a number of individuals, including their GP, surgeon and clinic nurse, before meeting the anaesthetist for the first time. Seeing this, one interviewee described the anaesthetist as “the last link in the chain” and felt that this position sometimes denigrated the part of the anaesthetist in caring for the patient. Others referred to their being the “reality check”, “last hurdle”, or the “last opportunity to opt out”, and some appeared to identify gate-keeping and safety net functions consistent with these perceptions.

In the role of safety net, a small number of anaesthetists commented that, on occasion, they may discover pertinent clinical details that had not come to light during earlier encounters with other health professionals. As the last clinician in the preadmission process to see the patient, it was the anaesthetist who sometimes “spotted the gaps” in the process leading up to surgery. Although these cases were the exception rather than the rule, these gaps could be attributed to the nature of the preadmission process: the involvement of multiple individuals with different professional backgrounds, each with their own focus and viewpoint.
presence of differing viewpoints was evident in the transcripts. Some anaesthetists seemed to believe that perhaps their surgical colleagues did not always look at “the global organism” and could be more goal-oriented or single-minded about operating, as evidenced by their references to “surgeon-speak”, “surgeon-personality” or the “surgical viewpoint”. Other anaesthetists identified differences in the perception of risk between the two specialties, describing anaesthetists as comparatively risk-averse and seeing “the glass half-empty” instead of sharing the surgeon’s perception of the “glass half-full”:

As a general rule I think . . . there’s a difference between anaesthetists and surgeons. Surgeons are the cup’s half full, and anaesthetists, the cups half empty. So we all have a one-sided view about risk, we’ll be worrying about the five per cent people who might have an MI, who might die, and the surgeons on the whole will be thinking about the ninety-five per cent of people who will do very well after their operation.

For this reason, a small number of anaesthetists seemed to perceive that, occasionally, other medical and nursing staff had not understood the significance of a piece of information to the potential outcome of surgery; not “asked [the patient] the right questions”; not conveyed the risks as they would have; or not ordered a specific test or investigation.

The discovery of new information, misinformation or misinterpreted information sometimes resulted in a “full consultant-to-consultant discussion” with the patient’s surgeon to clarify or revise the proposed surgical or anaesthetic plan to permit the surgery to go ahead. Anaesthetists described how they would either phone the surgeon or have a face-to-face conversation “to express the risk” and to bring both parties to a place of understanding about the surgical and anaesthetic choices and the implications of these choices for patient outcomes. One anaesthetist recounted an instance in which the proposed surgery went ahead with the involvement of additional specialists and invasive monitoring. Another commented on a case in which the surgery was ultimately performed under local rather than general anaesthesia as a result of a conversation with the surgeon to revise the plan for surgery. In their role as a safety net, anaesthetists appeared to act as an extra set of eyes, suggesting that their role was sometimes “[to] be honest with the surgeons”.

Beyond their role as a safety net, anaesthetists appeared to describe a role for themselves as a gatekeeper at AAC. Missing information, misinformation or simply multiple viewpoints about risk meant that anaesthetists were occasionally in the position of having to “put the brakes on” and postpone a patient’s surgery, or on rare occasions “to burst their [the patient’s] bubble” and cancel the surgery. The gate-keeping function also seemed to play out in situations where the surgeon appeared to defer the decision of whether to proceed with surgery to the
anaesthetist, especially for high-risk patients. Some interviewees described how surgeons might introduce the anaesthetist as an extra clinician in the decision-making process, even if this was sometimes too little too late:

They’ve [the patient] seen a surgeon who says you need an operation but I’m going to send you to the anaesthetist first. In other words, they’re passing the buck. And they know full well that some of those patients shouldn’t pass go. And so you’re trying to retrieve a situation sometimes that’s gone quite a long way down the line.

However, one anaesthetist perceived such deferrals as something that anaesthetists had “asked for”. She suggested that historically the anaesthetist had functioned purely as a gatekeeper or buffer, whose role was restricted to preparing patients for surgery after the decision to proceed had already been made. Such deferrals signalled an evolution in the responsibility of the clinic anaesthetist. They provided an opportunity to see the assessment as a specialist consultation in its own right and to have the necessary conversations with the surgical and medical teams about the “option among options”, provided that the patient arrived at the assessment expecting to have a conversation about whether surgery was warranted rather than expecting to be given the go-ahead for surgery. In setting up preoperative clinics and conducting the assessments on the wards, she suggested that anaesthetists had actively sought greater responsibility in the area of perioperative medicine:

[When] the surgeons are asking you for an opinion about the overall suitability and perioperative risk and it’s not been a “this person’s booked for surgery” . . . you can stop and behave like a consultant . . . We’ve asked for it by setting up these perioperative clinics and, and owning the assessments on the wards and we have actively sought this . . . It is our duty . . . It’s an evolution of our new responsibility as owning the patients’ cause we’ve never owned the patients.

In addition to their role as safety net and gatekeeper, a role for anaesthetists as informant and educator could also be elicited. Depending on the patient’s desire for information, their health status and the proposed surgery, anaesthetists may educate patients about different anaesthetic options; anaesthetic and perioperative risks; and other areas of concern or interest, as directed by the patient. Anaesthetists, like teachers, were also sometimes in the position of trying to engage a population that may or may not have any interest in learning about what might happen to them during and after surgery. At times, it appeared that anaesthetists could struggle to get patients to appreciate or engage in a conversation about why one anaesthetic technique might be preferable over another. Some interviewees reported using the patient’s medication list or their laboratory or echocardiogram results as teaching aids to enhance the patient’s comprehension of the risks that are associated with certain procedures or conditions.
Other anaesthetists used the Internet, with or in front of the patient, to seek out information on topics that they were “not 100% sure of”. Most anaesthetists acknowledged that the patient should understand what they are likely to experience in choosing to undergo surgery, and what risks they accept as a result of this decision. The anaesthetists’ role as educator and informant at clinic goes some way towards enabling this transfer of information to occur.

Anaesthetists described three key challenges in enacting the roles of safety net, gatekeeper and educator or informant. The first of these challenges was the difficulty in addressing “mixed messages” that patients had received about surgery or anaesthesia in the period leading up to the anaesthetic assessment. Some anaesthetists perceived that patients and other health professionals (rightly or wrongly) attached more importance to the surgeon and the surgery than they did to the anaesthetist and the anaesthesia. Anaesthesia was often perceived as a “sideline event” by both patients and some anaesthetists, leading one interviewee to suspect that patients saw the anaesthetist as an obstacle to their goal of having surgery:

> It’s difficult for us, because we’re a snapshot. Often we’re a distraction, a sideshow to the main event, a hurdle to be overcome . . . I wonder if sometimes some patients see us as an obstacle to be overcome.

Patients’ lack of understanding of the role of the anaesthetist coupled with the fact that the patient and anaesthetist usually met for the first time at the anaesthetic assessment could make it difficult for the anaesthetist to perform “damage limitation” without undermining others’ judgement or jeopardising the patients’ trust:

> I think sometimes patients look at you and they’re like, “Well who are you? I’ve never met you before.” I’ve been seeing Mr X [surgeon] for the last 2 years and suddenly you’re telling me that I can’t have this operation . . . I think often they have seen their GP a lot, their surgeon a lot, turn up to see you and then if you’re the gatekeeper or trying to tell them the risk and none of the other groups have it must be quite difficult for them to actually . . . take you seriously.

The second and third of these challenges related to the clinic setting, namely the distinction between the clinic and procedural anaesthetist and time constraints. Nine anaesthetists suggested that the distinction between the clinic and the procedural anaesthetist could pose some difficulties in trying to enact the role of educator or informant. This distinction limited the transparency or extent of the discussions that some anaesthetists might be willing to enter into in clinic, either out of fear of setting expectations about the anaesthesia or surgery that may not be met by the procedural anaesthetist, or based on the belief that the procedural anaesthetist was ultimately responsible for discussing the risks and benefits and subsequently gaining informed consent from the patient. Time constraints led another anaesthetist to
describe how he was “definitely not transparent” in his discussions of risk at clinic. He recalled how he would prioritise the discussion of some risks over others and would “bundle” risks up because there were only so many that could be discussed in the time available. Other anaesthetists took to ending their assessments with the “take home message”. This was seen to give them the best possible chance of successfully imparting key information to patients that may struggle to understand the gravity of their situation in the limited time available:

I’ve taken to summarising you know, to try and give one-liners. You know, “You have a significantly greater chance of dying than most people around this operation” or something like that.

Of the 29 anaesthetists interviewed, 19 specifically mentioned time pressures at the clinic, compared with 3 who believed there was adequate time to complete the consultation satisfactorily.

Finally, some anaesthetists perceived a division between surgery and anaesthesia that could prove challenging for the clinic anaesthetist. A small number of interviewees felt that, at times, they were left to speculate on the surgeon’s position about the patient undergoing surgery. Clinic letters and referrals did not always provide clues about whether the surgeon felt that the procedure was strongly indicated or a last resort. “Knowing what they’re [the surgical team are] planning and what they’re thinking” was described by one anaesthetist as the most challenging aspect of the anaesthetic assessment for high-risk patients. The perceived separation appeared to spill over into the division of labour for risk assessment and communication. The discussion of some outcomes with high-risk patients, and especially those for which the anaesthetist and surgeon could be considered to be jointly implicated, was described by one anaesthetist as being uncertain territory:

. . . total risk . . . It’s a little bit uncertain as to whose domain that is, but I think it’s a valid concern for anaesthetists because we’re sort of…implicated . . . [That the patient has] an okay appraisal of the overall thing . . . should be important to us.

Whereas some interviewees doubted whether the anaesthetist was the most appropriate clinician to convey this information and preferred to direct the patient back to their surgeon to discuss the matter, others felt obliged to inform the patient and, if need be, would “start at the beginning and recap the [surgical] risks” as best they knew how, even if they perhaps felt uncomfortable doing so. Recognising the role of the anaesthetist in shared, surgical decision-making, a small number of interviewees articulated a need for institutional information about outcomes, such as 1-year mortality, to better compare surgery with conservative treatment when assisting the patient in their decision-making about surgery and anaesthesia.
Several anaesthetists made suggestions to improve collaboration between anaesthesia and surgery. These interviewees believed that a collaborative approach to preoperative assessment could help them to gain insight into the “surgeon’s thinking” around high-risk cases and permit better sharing of information between the two specialties. Two anaesthetists explicitly expressed a desire to sit in on their surgical colleagues’ clinics because they had not had this opportunity since their training days. Having the ability to pre-discuss or post-discuss cases with surgeons was seen as a way to educate anaesthetists “on how surgeons think” – the process by which the surgeons arrived at the recommended plan for a patient. A combined surgical-anaesthetic clinic or multidisciplinary meeting for high-risk patients was specifically suggested by five anaesthetists. A joint clinic would permit anaesthetists and surgeons a private forum to air their concerns and disclose their reservations about pursuing surgery before formulating a mutually agreed course of action and presenting a “united front” to the patient.

5.4.3 Communicating the risk

In addition to revealing anaesthetists’ roles of safety net, gatekeeper and informant or educator, and the challenges they entailed, analysis of interviewees’ transcripts also elicited several elements which appeared to be common to the communication of risk during the anaesthetic assessment. Anaesthetists appeared to source information, qualify and quantify the risk, and convey uncertainty. These elements are described in the following subsections.

5.4.3.1 Sourcing the information

Anaesthetists drew on a wide number of information sources to inform their conversations about risk during the anaesthetic assessment (Table 28). Published academic studies; clinical guidelines; conferences; textbooks, such as Miller’s Anesthesia [729]; case reports published outside of journals; and institutional audits of specific procedures or cohorts of patients were among the sources named by anaesthetists as having influence on their assessment of risk. “Relevant scientific literature”, “published studies” or “journal articles” on perioperative morbidity and mortality appeared to be the most common sources of information about risk, although several anaesthetists commented that they did try to use institutional estimates of risk where possible (e.g. audit of outcomes for vascular or colorectal patients). One anaesthetist described himself as being “heavily influenced” by the comprehensive review of the risks of anaesthesia by Jenkins and Baker [54] that was published in Anaesthesia in 2003. Examples of other specific academic sources in use at the time, included RCRI [174, 730, 731], the Australian and New Zealand Registry of Regional Anaesthesia (AURORA) on the effectiveness and safety of peripheral nerve blockade [732], the Perioperative Ischemic
Evaluation (POISE) study [241] which evaluated the effects of perioperative β blockade in patients undergoing non-cardiac surgery, and Noordzij and colleagues’ [733] study on perioperative mortality and morbidity based on registry data for 3.7 million surgical procedures across hospitals in the Netherlands.

Anaesthetists seemed to use large, international studies for two purposes. First, as a source of background information to assist with their understanding of possible outcomes and factors that may affect these outcomes:

_One study showed blindness in 0.03% of cases [of spinal surgery] in America, but between the anaesthetists who do spine surgery here [at Auckland City Hospital] they haven’t had one case of blindness. So the practice is different_.

Second, some anaesthetists appeared to moderate or “move . . . their quoted figures or general explanation around” guidelines and large multicentre clinical trials. These interviewees extrapolated from studies in reputable journals to provide a ballpark figure of the degree of risk they believed a patient faced in choosing to undergo surgery:

_[I] don’t specifically go away and look up the paper or calculate it. Things like POISE have helped . . . you have ball park figures of, you know, over 65, having intermediate or major surgery, and so you think you just put them [the patient] into a better or a worse group than that and then factor in a bit of uncertainty . . . fictional ninety-five per cent confident intervals._

Alongside published academic literature, the majority of anaesthetists identified their own clinical experience as a source of information. All of the interviewees appeared to appreciate the limitations inherent in generalising from international studies to the individual patient. These limitations led some anaesthetists to rely increasingly on convenient heuristics and anecdotal experience as sources of information about risk:

_As I’ve got older, I have relied more and more on my anecdotal experience. Studies on anaesthetic risk or surgical risk tend to be limited to vascular patients because they’re the ones having events . . . extrapolating from these studies to other populations isn’t hugely valid._

Two anaesthetists specifically acknowledged that their personal experience was the most significant informational input into their estimate of perioperative risk, with one acknowledging that his estimates were “personal experience by about 80 per cent”.

Lastly, the patient’s medical record was described as a source of information about risk. Results from investigations such as a laboratory, ECG, echocardiogram, exercise tolerance or shuttle walk tests were used in conjunction with the medical history and list of current
medications to inform discussions about risk. Other documents in the patient’s medical record, including records of previous anaesthetics or letters from the surgical team, also contained useful information. While the contribution of each of these sources – published literature, institutional audit, clinical experience and the medical record – appeared to be difficult to isolate, the mix of sources gave rise to what one anaesthetist termed his “own risk models”:

... Internet, age adjusted mortality tables, perioperative medicine, conferences ... it’s ... amorphous, non-describable, you can’t separate out the component parts. You end up with your own risk models in your head which you hope are roughly similar to your colleague’s risk models and that’s what you use to describe to a patient.

Table 28. Source of information used to inform risk communication at AAC.

<table>
<thead>
<tr>
<th>Source</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Published academic studies</td>
<td>[732], [730], [241], [731]; [54]; [174]; Cochrane reviews from the Cochrane library</td>
</tr>
<tr>
<td>Clinical guidelines</td>
<td>ACC/AHA guidelines; US National Institute for Health Care and Excellence</td>
</tr>
<tr>
<td>Textbooks</td>
<td>[729]</td>
</tr>
<tr>
<td>Non-academic case reports</td>
<td>Medical Protection Society case reports, ACC reports, Health and Disability reports, ASA’s Closed Claims Analysis</td>
</tr>
<tr>
<td>Institutional audit</td>
<td>Institutional audits of specific patient groups including colorectal and vascular patients. The “mortality app” built as part of this PhD thesis.</td>
</tr>
<tr>
<td>Clinical experience</td>
<td>“Gut feel”, “case series of 50 or so over my career”, “personal experience by about 80%”.</td>
</tr>
<tr>
<td>Medical record</td>
<td>Results from investigations such as blood tests, echocardiogram, exercise tolerance and shuttle walk tests. Documentation such as the patient’s current list of medications, letters from the surgical team about what the options are for the patient and conversations with the surgeon about these.</td>
</tr>
</tbody>
</table>

5.4.3.2 Qualifying and quantifying the risks

Interviewees expressed information about anaesthetic and perioperative risk to patients both qualitatively and quantitatively. Risk disclosure during the anaesthetic assessment appeared to be a personal practice that varied considerably between anaesthetists and was likely to be based, at least in part, on differences between patients, including their medical condition and proposed surgery. Anaesthetists’ narratives tended to fall along a spectrum ranging from incorporating use of numeric estimates to convey incidences of risk to omitting numeric estimates in favour of the use of verbal qualifiers to express the likely risks.

At one end of the spectrum, a small number of anaesthetists preferred to “paint a picture with ... their conversation”. Examples of clinic anaesthetists qualifying risks for patients undergoing surgery are provided in Table 29. Anaesthetists in this group had a tendency to
qualify the magnitude of the risk with words such as “serious”, “high risk” and the probability that the complication could occur with words such as “rare”, “common” or “uncommon”. These anaesthetists described a strong desire to “stay away from numbers if possible” and avoided using numeric incidences of risk “unless absolutely pushed” by a patient.

Table 29. Examples of clinic anaesthetists qualifying perioperative risk.

- . . . it’s like getting on an aeroplane . . . there’s a really small risk of major problems. There’s probably a slightly higher risk of some turbulence and some minor complications, but you’re going to get through it.
- [Your case] is a relaxing day at work . . . compared to the person after you who I’ve booked intensive care for . . . this is a normal relaxing day at work.
- If it’s going to be a frequent thing I’ll say look the chances are you actually know somebody who’s had this happen to them, or you know somebody who’s somebody. And then go towards the town, and go towards New Zealand and go towards the world type of thing.
- I do talk to patients about the concept of being on a slippery slope and when they’re on the flat part of the curve they’re sort of okay and then something will tip them over and then they’re gonna go down very quickly.
- You need to make sure you have your affairs in order.
- . . . we do these cases frequently. I hate having to come to the ward to explain to people that they’ve had a complication and I think, you know, for you there is a real risk that I’m going to have to [do that].
- It is going to be a bumpy road and as an anaesthetist my job is easy. You’re going to be the one who has to do the hard work.

At the other end of the spectrum, some anaesthetists’ narratives included numeric incidences of risk for complications that they felt able to give reasonable estimates for. Examples of clinic anaesthetists quantifying risks for patients undergoing surgery are provided in Table 30. Across the group, numeric estimates were provided for a range of risks including perioperative mortality, stroke or MI; nerve injury associated with regional anaesthesia or positioning under anaesthesia, intraoperative awareness; oral and dental trauma, post-dural-puncture-headaches with epidurals; anaphylaxis; postoperative nausea and vomiting; sore throat; aspiration, likelihood of being ventilated in ICU; and postoperative cognitive impairment. Percentages appeared to be the most common format for common risks and natural frequencies, for example “one in 100,000” tended to be used to convey the infrequent nature of rare risks. However, three anaesthetists reported using natural frequencies instead of percentages based on the belief that patients have difficulty comprehending a percentage (e.g. “1 in 3 seemed to make more sense”). Finally, some anaesthetists appeared to supplement percentages with a natural frequency estimate to cover their bases (e.g. “So I might quote 10%, that’s one in ten”).

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Table 30. Examples of clinic anaesthetists quantifying risks.

- . . . if it was a whipples [major surgical procedure involving removal of the head of the pancreas, and a portion of the intestine and stomach] in an 80 year old, I’d say you’ve got a 5% chance of dying, you’ve got a 20–25% chance of needing a protracted stay in hospital from some complication like a leak or pneumonia. Best case scenario, 50% of the time you’ll be out of hospital in two weeks.
- I say 1 in 200 thousand, yeah. That’s what I quote as my death rate, but I actually think it’s a lot worse than that, I think it’s about 1 in 50 thousand.
- So if someone’s got a five per cent MI risk I’ll say, ninety-five patients out of a hundred like you won’t have an MI.
- I quote 1 in 2000 for a transient neurological deficits with epidurals, 1 in 200-300 for a post-dural puncture headaches with epidurals.
- I go one in two and a half thousand or one in five thousand, they [the patient] go argh! So I go “hang on a minute that’s less than one percent”.
- If you’re a betting man, you’ve got a ninety percent chance of surviving.
- I probably fall into a bit of a habit but I say nausea and vomiting and sore throats affect about a third of people afterwards and then we’re talking, depending on the type of anaesthetic, you know, there’s a one in five thousand risk, which is the number I’ve heard, of an allergic reaction in hospital.
- I’m not very good at quoting numbers to them and I think part of that’s coz of my other job in intensive care. I say . . . it’s a high risk procedure. It’s a 1 in 5 chance of dying. It’s not going to help you if you’re that 1 in 5 because it’s actually a 100% chance of dying. So it gives you an overall scheme as to where you fit into the population if we did 100 of you. But if it’s you that . . . dies, it’s not helpful for you or your family to know that . . . there’s another . . . 4 out of 5 people that are alive.

Others had no strong position on quantitative or qualitative estimates, but some patterns of disclosure did appear to emerge. Several anaesthetists suggested that they would qualify risk, but routinely used numeric estimates for rare, devastating complications to make it apparent to the patient that these were low-frequency events and were very unlikely to occur. In this way, numeric estimates were intended to reassure patients and to allow the anaesthetist to “back pedal” if he or she perceived that the conversation up until that point had left the patient feeling overly or unnecessarily frightened. Another anaesthetist described her tendency to avoid the use of quantitative estimates unless “it’s a decision for surgery or not surgery, and the decision’s close”. Still other interviewees recounted a two-phase approach, preferring to describe patients as being at low, moderate or high risk as a first-line approach and then following up with numeric estimates if necessary. Lastly, use of an alternative pictorial representation of risk appeared to be part of one anaesthetist’s practice. She explained how she would try to illustrate a measure similar to the number needed to harm (a common epidemiological concept) by drawing stick figures in squares before proceeding to strike them out with her pen:

*What I find works really well is to draw them a square and say okay, there’s a person in every one of these squares and here’s how many people we actually think we’re going to harm by doing this* [crossing them off with her pen].
Irrespective of the use of qualitative or quantitative estimates, nearly all anaesthetists compared the likelihood of an adverse event with the occurrence of everyday events, and those that didn’t believed that they probably should. Examples of these everyday events included plane and car crashes, winning Lotto, being struck by lightning and “getting kicked in the head by a horse”. Although, as one anaesthetist noted, occasionally this technique did “backfire” if the patient had experienced one of these events or knew of someone else who had. Still, several anaesthetists contrasted anaesthesia and surgery with the everyday event of going to sleep at night or running a marathon, to convey the idea that surgery is a not a restful experience; the human body is put under significant stress intraoperatively so there is always some degree of risk involved.

Anaesthetists gave various reasons for using or avoiding numeric estimates of risk. Providing numeric incidences was seen to provide a concrete estimate of risk, gave anaesthetists and patients “something to hang their hat on”, and gave the anaesthetist “a bit of credibility for the risk”. Other anaesthetists acknowledged that as doctors with a strong scientific and numeracy background, the use of numeric estimates to convey risk came with a sense of objectivity and familiarity:

“We [anaesthetists] like numbers, we like population studies . . . it’s fun, there’s a number and we can hang something on it.

Others supposed that numeric estimates were used because anaesthetists unwittingly assumed that these measures were equally valid or intelligible to the patient:

_I suppose because physicians tend to have a scientific background we’re used to dealing with numbers . . . [which] are automatically and largely more intelligible to us . . . They make sense to us [so] we assume they make sense in the same way or carry the same weight to most people._

Anaesthetists who included numeric estimates during their disclosure also cited the potential for patients to misinterpret verbal qualifiers such as “rare” or “occasionally”, which are inherently elastic. Ironically, the preference for avoiding disclosure of numeric estimates stemmed from a belief that the numbers were “just a guess” or that the patients themselves may struggle to interpret them.

Anaesthetists were also questioned about their practice of positively or negatively framing risk. Almost half of anaesthetists appeared to frame risk in a positive light, for example talking in terms of survival rather than mortality. Approximately one-quarter of anaesthetists reported doing this routinely. It seemed that the practice was important to “keep it in perspective” and to avoid “concentrating on the bad things”. Presenting the glass half-full
instead of the glass half-empty scenario appeared to be used as a tool to “get them [the patient] back in the right headspace” in the anaesthetist’s pursuit of an informed, but not terrified, patient. Conversely, anaesthetists’ practice of framing risk purely in a negative light functioned as “a reality check” for the patient and was employed to “balance things out” because risk was seen to have more gravity associated with it than benefit. Some anaesthetists believed that the patients had already decided on surgery as a solution to their medical condition before arriving at the anaesthetic assessment. They saw no need to encourage the patient further, believing that patients already tended to be (overly) optimistic about the benefits of undergoing surgery. Still, others described their practice of “flipping the risk” as dependent on “how I wanted the conversation to go”. If they were more inclined to dissuade the patient from undergoing surgery as a first-line treatment or from forming a strong opinion about one anaesthetic technique over another, they might “spin it so they’ll [the patient] be persuaded” and acknowledged the ethical dilemma this presented.

Through analysis of the transcripts, there also appeared to be some variation in the time period for which risks were considered. The majority of anaesthetists discussed risk for the period extending from the beginning of the surgery anywhere up until 30 days postoperatively. Most considered this timeframe to be a reflection of the perioperative period and hence was “what was available” in the literature. Specific longer-term outcomes, such as nerve injury beyond 6 weeks, mortality at 1 year postoperatively, chronic pain at 1–2 years postoperatively and postoperative cognitive dysfunction beyond 1 week, were discussed if the anaesthetist believed these to be relevant to the proposed surgery or the patient specifically asked about these risks. Five anaesthetists, two of whom were specialist liver transplant anaesthetists and one of whom had developed a keen interest in risk communication, explicitly provided information about mortality beyond 30 days postoperatively. Although one of these anaesthetists did not routinely talk about 6-month or 1-year mortality, she said she might include references to longer-term mortality if the patient had significant life-limiting comorbidities and she was attempting to dissuade them from having surgery:

_I might say to them, “Well the statistics might say that you might die from your concurrent disease within a certain time period.”_

In the broader context of shared decision-making, anaesthetists attempted to help high-risk patients to understand what their postoperative course might entail. They encountered patients who failed to appreciate their significant risk for a perioperative complication or could not conceive of what the anaesthetists described as “the grey area”, “middle ground” or “a fate worse than death”. Hence, some anaesthetists spoke about the recovery period after surgery
Anaesthetists recounted their use of “best and worst case scenarios” to contextualise risks, with some describing the significant period of slow rehabilitation which could require placement in a rest home or other care facility after surgery. Others conveyed the idea that the patient might be weaker after surgery and could take months to “get back to normal again” or might never regain the level of function that they had prior to surgery. One anaesthetist framed these conversations in terms of time in hospital versus time with family, and used the cohort of dialysis patients to illustrate her point:

You can have 2 years with dialysis, 1 which is going to be in dialysis [and 1 with your family] or you can have no dialysis and spend a year with your family. Either way you only get a year.

Her conversations with patients canvassed what it might mean in the longer term if the patient did suffer a perioperative complication. She spoke about the extent to which the patient might have to interact with the hospital and other clinicians after experiencing a complication “because it’s not just that it’s [a complication has] happened, it’s ‘So what?’ when it [does]”.

The nature of these conversations appeared to be influenced by prior professional training. Four anaesthetists, two of whom had spent significant time in ICU, one of whom had dual roles as an anaesthetist and an intensivist and one of whom trained in geriatric medicine prior to anaesthesia, were acutely aware of how their professional training influenced their conversations with high-risk patients about postoperative outcomes. As intensivists and geriatric physicians, these anaesthetists were often intimately familiar with the postoperative care required for elderly, comorbid patients and others “who didn’t do so well”. These interviewees were able to draw on this experience in their discussions about risk with patients:

I go through those [best and worst case scenarios] . . . I did medicine before I did anaesthesia, and I did geriatrics . . . I took all the people who didn’t do well and had to go through rehab or I had to place in rest homes after operations . . . Going home on your expected day seven or dying are not the only two options.

5.4.3.3 Conveying uncertainty

Having found variation among qualitative and quantitative approaches to risk disclosure, the finding that anaesthetists also varied in their approach to describing uncertainty inherent in their estimation of risk is not unexpected. Examples of clinic anaesthetists conveying uncertainty for patients undergoing surgery are provided in Table 31. Interviewees conveyed uncertainty implicitly, explicitly or preferred not to convey information about uncertainty at all. Anaesthetists who implicitly addressed uncertainty of their estimates recounted their use
of the words “about” or “approximately”, provided their estimates as a range, or prefixed statements with phrases like “for the average patient”:

*I use words like about. I do quote a range, like I don’t say the risk is five per cent. I say it could be as low as or could be as high as . . .*

Anaesthetists who were explicit about the uncertainty in their estimates tended to communicate the absence of “a perfect number”. “The numbers . . . [are] incredibly soft” because they are obtained from studies of large numbers of patients at different hospitals, so the anaesthetist cannot “predict the path the patient might take”. Some anaesthetists declared that they did not have a “crystal ball” so they could only provide patients with “their best guess”, “a ballpark figure” or “the best evidence we’ve got”. One anaesthetist used the discussion of uncertainty as an opportunity to reassure patients of the small possibility of an adverse outcome. He informed patients that he did not have reliable data about exactly how risky their proposed surgery was because the perioperative period is so safe. In doing so, he alluded to the infrequency of adverse outcomes and the large number of patients that would need to be studied to reliably detect an event rate. Finally, a small number of anaesthetists preferred not to discuss uncertainty with patients, believing that this information did not contribute to the patient’s understanding of the likely risks. One anaesthetist, for example, described his reluctance to talk about uncertainty inherent in almost any estimation he made. Instead, he preferred to see his position as being “to clarify [based on the best available information] rather than confuse” patients.

**Table 31.** Examples of clinic anaesthetists conveying uncertainty.

- *Unfortunately I don’t have a crystal ball.*
- *I say look we really don’t know and I often say to people if you look at the whole population you know this is how many people will run into problems with this but we don’t know specifically what it is for you.*
- *I would generally say that because it is so safe we don’t have reliable data as to exactly how risky these things are, but it’s probably in the order of magnitude of blah, blah blah.*
- *That’s my experience, that’s what we’ve found over here, that’s the best that I can tell you and it still is no guarantee.*

In sum, risk communication during the anaesthetic assessment appeared to be a personal practice that varied considerably between anaesthetists. Published literature, institutional audit, clinical experience and the patient’s medical record combined to yield mental models of risk. The outcomes of these models were described to patients using qualitative and/or quantitative estimates related to real-life events, framed positively or negatively, mostly in the context of 30 days postoperatively, and for which uncertainty was discussed implicitly, explicitly or not at all. Decisions about what to disclose and how best to disclose this
information were based on the anaesthetist’s reading of the situation, with the goal of helping patients to make the choices about surgery and anaesthesia that best met their needs.

5.4.4 Sociotechnical analysis in the context of the BI prototype
The previous sections have described three themes – the conception of work; roles, relationships and responsibilities; and communicating the risk – from a series of qualitative interviews that were undertaken as part of our work in the sociotechnical analysis quadrant of the Multiview2 framework. The implications of this work for the revision of the framework are shown through comparison of the indicative and stereotypical methods of Multiview2 with what actually occurred in practice. The stereotypical sociotechnical analysis draws from ETHICS [543], ethnography [552, 553], the Scandinavian School of participatory design [554] as well as a general interest in how work is accomplished in actuality [555]. In examining the sociotechnical work that was conducted in practice, a fully fledged ETHICS or ethnographic investigation was not considered viable on the basis of the scope of the project. There were three reasons for this: (1) the BI artefact was a prototype rather than a complete build, (2) its use was not mandatory and, (3) it was developed as a stand-alone initiative that was perceived to have minimal impact on anaesthetists’ working practices at AAC. However, the view remains that human considerations are equally important as technical ones [534] and an understanding of work practices and the nature of healthcare work underpins the efforts to balance these considerations.

5.5 Discussion
The research presented in this chapter was undertaken to address the first and second objectives of this thesis. The first objective was to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in the healthcare sector. The second objective was to explore the work of risk communication at AAC with a view to understanding how this work is accomplished in actuality. This chapter focused on the work we undertook in the sociotechnical analysis quadrant of the framework. Four key findings were reported; the first three relate to the exploration of the work of risk communication and the fourth relates to the use of Multiview2 to inform the development of a BI prototype. These learnings are discussed in the subsections that follow.

5.5.1 Learnings about the work of risk communication
The qualitative interviews with specialist anaesthetists yielded three key findings. First, anaesthetists characterised informed consent as a reflexive, albeit imperfect, patient-centred communication process that involves the giving and receiving of information about surgery
and anaesthesia by an anaesthetist and a patient with the capacity to understand this information. Second, despite general agreement about the meaning of informed consent, risk communication during the anaesthetic assessment appeared to be a personal practice that varied considerably between anaesthetists. Third, the wider conception of work throughout the preadmission process was characterised by distributed decision-making, multiple viewpoints and by evolving (and sometimes inconsistent) knowledge bases of all involved.

The strength of this study lies in its use of qualitative methods to gain valuable insight into clinic anaesthetists’ perceptions, challenges and approaches to risk communication for patients undergoing elective surgery. Anaesthesia is unique among other medical specialties. The purpose of anaesthesia is to facilitate surgery; only rarely does anaesthesia have any therapeutic value in itself [734]. Many patients will not usually have a prior relationship with the anaesthetist because anaesthetists have comparatively transient and short-lived relationships with patients [734]. Perhaps for this reason, patients may know little about anaesthesia or the roles and responsibilities of the anaesthetist [703, 735-738]. Despite these peculiarities, neither the anaesthetic assessment nor the informed consent conversation usually occurs in front of other anaesthetists. Sharing of strategies for dealing with practical challenges such as time limitations or challenging communications may not occur routinely or formally and hence difficulties may go unrecognised [739]. This study provided anaesthetists with an opportunity to engage in thoughtful reflection and perception of circumstances and interactions pertinent to their disclosure of risk. In doing so, the research has shed light on the range of challenges and issues, patterns and practices, beliefs and values that might otherwise remain behind the closed consultation room door.

The strengths of this study are tempered by its shortcomings, however. Research about people’s working world is, arguably, best studied from the point of view of those who live it [740]. Qualitative methods including interviews or fieldwork can be used to understand meaning or to grasp interviewees’ definition of a situation [740] and, in doing so, give a higher probability of valid data. Yet, when people are interviewed about their work, their talk can also be misleading, not only because they tend to rely on stereotypical or normative language which may not truly reflect how they accomplish their work [713], but also because most of what they know about their work is tacit in nature. Tacit knowledge “indwells” [741] and is not easily articulated because it is tied to the senses, to physical experiences, intuition or implicit rules of thumb [693]. Supplementing the interview data with observation may have added an additional dimension to the findings, permitting a truer picture of the actuality of work and the transfer of tacit knowledge through practice, guidance, imitation and
observation (socialisation) or codification (externalisation) [693]. Despite this limitation, all interviewees appeared to be relatively candid (e.g. occasional use of profanity or remarks made in jest). Besides, people are known to give open, frank and accurate accounts about aspects of their work in interview situations as well as actual situations [712, 713].

Studies on risk communication in anaesthesia are few and rarely explore the nature of the work. Based on a review of the literature discussing patients’ attitudes towards and preparation for anaesthesia from Roizen and Klafta’s [704] overview of the essential elements of communication in medial encounters [742], Zollo and colleagues [710] proposed nine components of an appropriate preoperative evaluation: initiating the session, getting the patient’s perspective, gathering information in the form of a history and physical, describing the anaesthetic plan, describing anaesthetic risks, discussing pain control, and closing the interview. Many aspects of the anaesthetists’ communications disclosed in this study could be mapped to these different dimensions. The “warning shot” was a means of initiating the session; the patient’s perspective was actively sought through direct questioning and was reassessed by means of “checking in”; risks of anaesthesia and surgery were conveyed qualitatively and/or quantitatively; “the paper chase” permitted information gathering for the history and physical; and the consultation might end with the anaesthetist’s delivery of the “take home message”. However, the distinction between the roles of the procedural and clinic anaesthetist was found, at times, to limit the extent of the discussions about the anaesthetic plan (including pain control) that anaesthetists might be willing to enter into in clinic. This requires consideration, especially in light of perceived time constraints, because preadmission anaesthesia clinics are known to confer a number of benefits, including minimising operating room delays and cancellations [99, 743-745], and are also considered one way of ensuring that the elements of informed consent may be met on the day of surgery [734].

Components aside, every anaesthetic assessment is different. Previous studies have reported variation in the number and sorts of risks anaesthetists disclose to patients before surgery [706-708], but this study found considerable variation in how anaesthetists impart this information. An integral part of the anaesthetic assessment is the anaesthetist’s provision of understandable information about the benefits, harms and expectations of surgery and other treatments. There are, without doubt, many factors that may impede the delivery or understanding of this information. Anaesthetists reported diverse factors including cognitive difficulties, age, low educational achievement, poor numeracy skills and language differences or cultural barriers, all of which have been reported previously in the literature [723, 734, 739, 746]. Noting advances in surgical and anaesthetic techniques and the changing demographics
of the surgical population, such that higher-risk surgery is being performed on higher-risk patients, Dhesi [29] suggests that a more individualised approach to shared decision-making is becoming increasingly vital. Although communication tailored to patient need undoubtedly has benefits [747], some anaesthetists had experienced difficulties assessing what information they ought to provide to patients, at what level of detail, or how best to impart it. Previous studies on preoperative communication have revealed some general trends, but also some important differences, in patients’ desire for information in Canada [699], Scotland, Australia [697], Denmark [698] and the US [700], suggesting that there is no simple answer to the difficult judgement about what information should be provided to patients. Rather, the use of words and numbers, metaphors and analogies, gestures and mannerisms, formats and framing only ever unfolds in the doing [748]; that is, in the “constant interaction with the contingent circumstances that make up the situation” in which the work is situated [626, p.92], reflected in an “ask-tell-ask” approach to presentation of information [29].

The study has also shed light on multiple viewpoints that feature throughout the preadmission process. Several interviewees shared their belief that anaesthetists and surgeons tended to perceive and disclose risk differently. Indeed, the perception of fundamental differences between the specialities is shared by an anaesthetist interviewee in Powell and colleagues’ [749, p.811] study on intraprofessional cooperation: “. . . we become an anaesthetist or a surgeon. We’re fundamentally different people.” Evidence of differences in perception of risk between the two specialties has also been demonstrated [718]. However, differences in perspective, background and function make a strong case for the benefits of shared decision-making for all parties, where each clinician plays to their strengths and is complemented by the opinion and wisdom of the other. As the population ages and the prevalence of chronic degenerative disease grows, both disciplines will increasingly be faced with preparing older and sicker patients [86, 87, 378] for elective surgery. Noting the inseparability of anaesthesia from the total care of the patient [750], Kehlet [42] suggests that efforts will be needed to further improve interdisciplinary collaboration, not only in pursuit of the “common task” [750] of providing a successful therapeutic procedure, but also in the joint determination of the best course of treatment for the individual patient. In her discussion of the professional requirements for collaboration between the disciplines, Sutherland [41, p.150] suggests that collaboration is “enacted in how each represents the other; in what way the tasks of each are distinct, and which are shared”. A joint forum to discuss high-risk cases, as was suggested by some anaesthetists and in the literature [751], may go some ways toward furthering collaboration for the betterment of patient perioperative care [42].
This study has a clear implication for clinical practitioners: the interactional and circumstantial influences on anaesthetists’ communications with patients, as part of the shared decision-making that occurs prior to surgery, are complex. Preoperatively, there exists potential for multiple viewpoints and misinformation or misinterpretation, with many participants playing varied roles, each with their own perspective on the nature of the risks of undergoing surgery and anaesthesia. Helping patients to come to an appropriate decision that best meets their needs depends on successful communication and collaboration between anaesthetists, surgeons and patients. Conveying information about the risks of undergoing surgery and anaesthesia takes time, skill and sensitivity, often requiring much sentimental and information work. This work does not comprise of pre-fixed workflows or formal task descriptions, not is it exemplified by a laundry list of risks, each to be disclosed and meticulously checked off. Rather, the anaesthetist’s work involves taking cues from the patient and using these to construct interpretations of their and others’ work that work for the patient. It seems only fitting that the anaesthetist’s communications are viewed as “people work” if we are resolved to carry out shared decision-making that is patient-centred in every sense of the word.

Although this research has uncovered valuable insights into the practice of risk communication, important questions remain unanswered and further work is needed to address these. First, participants in this study were limited to specialist anaesthetists in the clinic setting, and therefore triangulation of subjects [586, p.67] is needed to explore the nature of work from the perspective of trainee anaesthetists. In a study of trainee anaesthetists’ experiences and difficulties in obtaining informed consent, Waizel [739] found that interviewees encountered ethical, practical and relational difficulties in obtaining informed consent. Although the narratives were provided by trainees at various levels of seniority, the authors recognised their own experiences in the narratives, suggesting that specialist anaesthetists face many of these challenges too. However, it remains to be seen whether the nature of this work – those circumstantial and interactional influences – are perceived differently by trainee anaesthetists. Second, further research into surgeons’ work of risk communication through qualitative interviews is needed. Decisions about whether to proceed to surgery include discussion between a surgeon and the patient and perhaps the patient’s significant other [751]. Exploring surgeons’ work of risk communication as well as anaesthetists’ may go some ways towards understanding how risk is perceived and disclosed and further improve shared decision-making between the specialties. Finally, further work is needed on the legal requirements, components and interpretations regarding informed consent because these aspects did not feature heavily throughout the analysis. Tensions between the
legal requirement and the need to satisfy patients’ information needs have led some authors to suggest that the patient should drive the informed consent process, even if this runs counter to the legal requirements [752]. Yet, the fact remains that informed consent is a legal instrument that lets patients define their own interests and guard against unwanted intervention [753]. Studies specifically designed to address these aspects of work could yield results that may improve patient-centred preoperative care.

5.5.2 Learnings about sociotechnical analysis in the context of BI development

The previous subsections have discussed the learnings about the work of risk communication in the context of the broader literature and, as a result, have elicited questions that are ripe for further research. The implications of this work for sociotechnical analysis in the Multiview2 framework are now briefly considered in the context of the development of a BI in the healthcare setting. Consistent with the work that was undertaken in the organisational analysis, information modelling and software development quadrants of the framework in Chapter 4, this study identified a fourth and final stereotypical role in BI development: perceiving and interpreting, the outcome of which was an appreciation of work practices. Accordingly, the methods matrix has been annotated with both the stereotypical role and the outcome of enacting this role. The sociotechnical analysis quadrant is given the appearance of being divided into two parts to emphasise the need to focus on both the work practices of those individuals who enter data into IS as well as of those who wish to consume it at a later date. The revised Multiview2 framework is shown in Figure 40.
Figure 40. The Multiview2 approach to systems development [534] (top) compared with the revised Multiview2 framework for BI development after PAR cycle 2 (bottom).

Use of the Multiview framework has not been widespread in the IS/IT literature and this study would appear to be one of the few that has used semistructured qualitative interviews to explore the broader nature of work within the sociotechnical analysis quadrant. In their paper on the redefinition of Multiview to Multiview2, Avison et al. [534] illustrated the four components of the framework using an AR project conducted in the wind tunnel department of an aerospace organisation. Sociotechnical analysis was conducted informally through participant observation to gain insight into how operators and supervisors carried out their work. Vidgen’s revision of the Multiview2 framework for web development five years later [533] broadened the aim of the sociotechnical analysis in the classic ETHICS form to a more general concern with user satisfaction in the e-commerce environment. Citing difficulties in gaining access to external customers, user satisfaction was assessed using a web-based questionnaire.

Perhaps the only other study to use qualitative interviews and Multiview2 appeared in the same year. Kawalek and Wood-Harper [598] presented an analysis of the ISD method used in a major multinational ERP implementation through a series of interviews with stakeholders, which were then related to the Multiview2 framework. However, the study used Multiview2 as a general schema rather than a test of the goodness of fit, and because of this the resulting method descriptions diverged from those stereotypical activities proposed by the authors of
Multiview2 [534]. Despite this, the combined use of Multiview2 to structure the enquiry into the characteristics of the implementation method and qualitative interviews to gain a rich account of the research problem yielded a conception of user participation that was far from the emancipatory form envisioned by the ETHICS approach.

Sociotechnical analysis seeks to understand systems requirements through analysis of everyday conditions of work and through informed practice of workers and managers alike [4, 555, 598]. This is an interpretive exercise in every sense of the word as the researcher seeks to understand “the complex work of lived experience from the point of view of those who live it. This goal is variously spoken of as an abiding concern for the life world, for the emic point of view, for understanding meaning, [and] for grasping the actor’s definition of a situation” [740, p.118]. Although the problems and pitfalls of interviews are many [589], the artificiality of the interview, requiring a specific time and place to be set aside for the express purpose of questioning someone [458], could also be considered one of its advantages. The qualitative interview gives focus to the subject’s world [458] by sanctioning a time and space away from the pressures of day-to-day work where busy participants – in this case, busy doctors – can engage in thoughtful and purposeful reflection on interactions and perceptions of those interactions. The value of the qualitative interview in the sociotechnical analysis quadrant of Multiview2 in gaining a profound understanding of how participants really carry out their work cannot be underestimated.

5.6 Conclusion

This chapter has presented the findings from the second PAR cycle. Research in this cycle sought to address the first and second objectives of this thesis. The first objective was to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in the healthcare sector. The second objective was to explore the work of risk communication at AAC with a view to understanding how this work is accomplished in actuality. The research was presented using the fourth and final quadrant of the methods matrix – sociotechnical analysis. Qualitative interviews with specialist anaesthetists were conducted as part of the work in this quadrant. Through analysis of these data, I found that the interactional and circumstantial influences on anaesthetists’ communications with patients, as part of the shared decision-making that occurs prior to surgery, are varied and complex. The indicative and stereotypical methods of the Multiview2 sociotechnical analysis were contrasted with the use of qualitative interviews as part of the ISD. This exercise led to the second and final revision of the Multiview2 framework which is thought to be appropriate for BI development. Having previously described the build of the BI prototype in Chapter 4 to
address the technical aspects of development, and now the nature of the work of risk communication to conceptualise the social aspects in this chapter, the next chapter describes the third and final PAR cycle, which was performed to assess the value of the data in the BI prototype for use in preoperative risk assessment and communication.
Chapter 6: Perioperative mortality among patients undergoing non-cardiac surgery: A retrospective analysis of RCD

6.1 Introduction

In Chapter 5, I presented the findings from the second PAR cycle, which provided an appreciation of the work of risk communication at AAC and further revisions to the Multiview2 framework for BI development. In this chapter, the findings from the third PAR cycle are presented (Figure 41). Research in this cycle sought to address the third objective of this thesis: to describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. With the appeal of a BI prototype demonstrated (detailed in Chapter 4), the present study allowed us to assess the value of its information for the purpose of anaesthetic risk assessment and communication, based on statistical analysis and comparison with international literature.

Figure 41. Data collection and analysis for PAR cycle 3.
First, this chapter provides a short review of the background literature. This review is followed by a summary of the data collection and analysis methods used. Next, I describe the key findings from the study. Following on from the findings, international comparisons are drawn (where appropriate) in the discussion section to assess the value of the information in the prototype for the purpose of risk assessment and communication. The chapter concludes with a summary of the findings.

6.2 Background

Worldwide, more than 200 million major surgical procedures are performed each year [754], but the risk of death following surgery and anaesthesia is not well understood [32]. Conservative estimates suggest that between 1 and 2.5 million adults will die within 30 days of non-cardiac surgery annually [754]. A recent cohort study which looked at almost 47,000 non-cardiac procedures across Europe reported an in-hospital mortality rate of 4% [336, 755]. This is in stark contrast to other large observational studies which suggest all-cause 30-day mortality lies in the vicinity of 1–2% [343, 344]. Together, these studies imply that considerable variation in perioperative mortality rates exists in the international literature.

It can be difficult to generalise findings from studies on perioperative mortality in other countries, regions or hospitals. Significant differences exist in how healthcare and hospitals are organised and how RCD are collected [421]. Variation in mortality rates is likely to reflect, at least in part, differences in patient characteristics and the quality of perioperative care [756]. Many studies use specific cohorts of surgical patients (e.g. cardiac, vascular or transplant), limited hospital participation or variable reporting timeframes [632], ranging from death in-hospital [634, 635] until 6 weeks after surgery [642]. There are few, if any, ongoing studies that provide information about the epidemiology of perioperative mortality that can be compared with individual hospitals across NZ.

The analysis of data that are gathered directly from the patient care environment may provide valuable insights into perioperative mortality that are relevant to anaesthetists’ own clinical settings [358, 421]. Information about institution-specific, perioperative risk may be obtained from RCD in HISs. Using RCD, we sought to estimate the risk of perioperative mortality, an outcome that affects a small, but important, number of patients after elective surgery [618]. Specifically, we sought to describe 30-day and 1-year mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012.
6.3 Materials and methods

A single-centre, retrospective cohort study was conducted using RCD from three HISs. Approval for this study (NTX/12/EXP/105/AM01) was given by the New Zealand National Health and Disability Ethics Committees (1 The Terrace, PO Box 5013, Wellington, NZ). The authors had access to the necessary databases consistent with the objectives of this research. The reporting of this study adheres to the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement [757].

6.3.1 Data sources

We obtained data from three main sources: Auckland City Hospital’s PAS, PIMS and AIMS. The PIMS database included information on every surgical procedure that occurred in the hospital from November 2002 onwards. Each record included the following information: patient’s name, age, sex, ASA score, type of surgery (emergency or elective), surgical specialty, primary operative procedure and up to six additional secondary procedures coded with the ACHI, start and finish time and date of surgery, and whether the surgery was cancelled. The PAS database provided information about patient demographics and inpatient and outpatient episodes. Each record included the patient’s name, age, sex, postcode of residence, date of death, admission and discharge date and time, principle diagnosis and up to 98 additional diagnoses and procedures coded with ICD-10-AM and ACHI. The AIMS stored information about every general and regional administered at the hospital from June 2005 onwards. Each record included the generic name and dose for all anaesthetic drugs given during surgery, the patient’s name, age, sex, medical history, ASA score, name of surgical procedure, type of surgery, and physiological data such as blood pressure, heart rate, respiratory rate and end tidal concentration of volatile anaesthetic agent.

6.3.2 Data extraction

We extracted 10 years of demographic and clinical data by a process of exact deterministic data linkage using shared internal patient identifiers for patients who underwent non-cardiac surgery at Auckland City Hospital from November 2002 to October 2012 (Figure 42). Our study sample included all patients with an electronic record in the PIMS who underwent general, urological, vascular, orthopaedic, neuro-, gynaecological or otorhinolaryngological surgery between November 2002 and October 2012. Patients were ASA1–5 +/- E and aged 16 years or older at the time of surgery. We excluded surgeries performed by cardiothoracic, transplant, radiology and maternity services because patients admitted under these services commonly receive care within separate dedicated pathways [162]. Day-stay procedures were excluded because the risk of perioperative mortality in the outpatient population is low [151].
We were careful to exclude surgeries that were cancelled and those that did not include a valid procedure code, and invalid or secondary NHIs (see Chapter 4). We chose one random surgery per patient per year to include in the dataset. This decision ensured the least biased sample of surgeries with respect to time of year and permitted the calculation and comparison of mean crude mortality rate within both 30 days and 1 year postoperatively from a single base dataset. Death within 30 days and 1 year of surgery is a dichotomous “yes/no” value irrespective of the number of times the patient returned to have surgery in each period or whether these additional surgeries were acute or elective.

![Figure 42. Study profile.](image)

### 6.3.3 Outcomes
The primary outcome was all-cause 30-day perioperative mortality, which was calculated from date of surgery to date of death [32, 58, 620]. The secondary outcome was all-cause 1-year perioperative mortality, which was calculated in the same way. Death after surgery is widely reported, describes an unambiguous event, and the data needed to calculate it are readily available [54, 421, 620, 621]. Surgeries were grouped by the surgical service under which they were performed to improve measurement of the outcome (see Chapter 4).

### 6.3.4 Statistical analysis
Descriptive analysis was first performed to describe the characteristics and outcomes for patients undergoing non-cardiac surgery. Descriptive statistics were calculated separately for each of the two-year groups in the study period and for the total 10-year period. These statistics were calculated for combined elective and emergency surgeries and also separately for emergency and elective surgeries. Categorical data are reported as absolute numbers (n)
and proportion (%), and continuous data are reported as mean with standard deviation (SD) or median with interquartile range (IQR). Comparative analysis to test for differences in casemix over time was undertaken using the Chi-square test, or analysis of variance (ANOVA), as appropriate.

Logistic regression analysis was performed to examine the impact of patient- and surgery-specific factors on 30-day perioperative mortality for patients undergoing non-cardiac surgery. Consistent with the literature, models were constructed on three sets of data. The first included all surgeries (both emergency and elective), the second included emergency surgeries only and the third included elective surgeries only. Each potential explanatory variable was entered separately in a univariable regression model; multivariable regression analyses were performed afterwards [655]. Variables were selected based on sound clinical and scientific rationale and had a low rate of missing data. The results of the models are reported as crude, unadjusted odds ratios (OR) with 95% profile likelihood confidence intervals (CIs), as well as ORs that are adjusted for patient- and surgery-specific variables.

Unadjusted ORs with 95% CIs for 30-day perioperative mortality were calculated for each of time period, age, gender, ethnicity, ASA score, grade of surgery, duration of surgery (more than 2 hours or not), surgical speciality and surgical code block. Adjusted ORs with 95% CIs were calculated to control for the same variables with the exception of surgical code block. This variable was removed because it had a high number of categories that produced unstable \( \beta \) estimates in the logistic regression. Profile-likelihood CIs were used instead of traditional Wald-type CIs. Profile-likelihood CIs are considered to produce more accurate results when the sampling distribution of the estimate is not normal, which is often the case for smaller samples or sparse data [758]. All analyses were conducted using R, version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

### 6.4 Results

A total of 104,699 surgeries performed at Auckland City Hospital from 2002 to 2012 were included in this study. Of these, 35894 (34.28%) were emergency surgeries and 68,805 (65.72%) were elective surgeries. Demographic and outcome information for emergency and elective surgeries performed between November 2002 and October 2012 is presented in Table 32. During 2002–2012, general surgery (27.53%) was the most frequently performed type of surgery, followed by orthopaedic (20.52%) and gynaecological surgery (17.36%). Higher numbers of surgeries were performed on female patients (54.22%), European peoples (63.61%) and patients with an ASA score of 1 or 2 (72.55%). Almost two-thirds of surgeries performed during 2002–2012 were categorised as intermediate or major surgery (66.01%).
Mortality in the first 30 days following surgery was relatively infrequent (1,581 deaths during 2002–2012). The overall crude 30-day perioperative mortality rate for the 10-year period was 1.51% of surgeries. The annual rate decreased from 2.01% for November 2002–October 2004 to 1.21% for November 2010–October 2012. Mortality in the first year following surgery was comparatively more frequent (6,517 deaths during 2002–2012). The overall crude 1-year perioperative morality rate for the 10-year period was 6.22% of surgeries. The annual rate decreased from 7.46% for November 2002–October 2004 to 5.07% for November 2010–October 2012.

Among emergency surgeries included in the study, orthopaedic surgery was the most frequently performed type of surgery (40.68%), followed closely by general surgery (32.84%) (Table 33). Emergency gynaecological and otorhinolaryngological surgeries were performed comparatively infrequently. Patient demographics were similar to those for combined elective and emergency surgeries, with higher numbers of emergency surgeries performed on European peoples (64.11%) and patients with an ASA score of 1 or 2 (68.28%). However, more male patients (53.73%) underwent emergency surgery than female patients during the same period. The proportion of intermediate or major grade, emergency surgery was similar (67.50%) to the proportion of intermediate or major grade, elective surgery (65.22%). There were 1,136 deaths within 30 days postoperatively. The overall crude mortality rate for the 10-year period was 3.16% of emergency surgeries and the annual rate ranged from 2.78% to 3.87% of emergency surgeries. There were 3,267 deaths within 1 year postoperatively. The overall crude mortality rate for the 10-year period was 9.10% of emergency surgeries and the annual rate ranged from 8.21% to 10.40% of emergency surgeries.

Compared with emergency and elective surgery combined and emergency surgery alone, Gynaecological surgery was the most frequently performed type of elective surgery (25.04%) (Table 34). Vascular surgery (6.36%) and neurosurgery (7.01%) were the least frequently performed types of elective surgery. Female patients (58.36%), European peoples (63.35%) and patients with an ASA score of 1 or 2 (74.95%) were again the most prevalent. Mortality in the first 30 days was lower than emergency surgery in the same period, with 445 deaths during 2002–2012. The overall crude mortality rate for the 10-year period was 0.65% of surgeries. The annual rate was between 0.46% and 0.92% of surgeries. There were 3,250 deaths within 1 year postoperatively. The overall crude mortality rate for the 10-year period was 4.72% of elective surgeries and the annual rate ranged from 5.73% to 3.65% of elective surgeries.

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<td>284 (1.21%)</td>
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<td>within 1 year postoperatively</td>
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<td>2869 (12.22%)</td>
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<td>Mean crude mortality within 1 year postoperatively</td>
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<td>Grade of surgery, intermediate or major</td>
<td>3839 (68.16%)</td>
</tr>
<tr>
<td>Surgical specialty</td>
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<tr>
<td>General surgery</td>
<td>1609 (28.57%)</td>
</tr>
<tr>
<td>Gynaecology</td>
<td>405 (7.19%)</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>351 (6.23%)</td>
</tr>
<tr>
<td>Orthopaedics</td>
<td>2392 (42.47%)</td>
</tr>
<tr>
<td>Otorhinolaryngology</td>
<td>179 (3.18%)</td>
</tr>
<tr>
<td>Urology</td>
<td>387 (6.87%)</td>
</tr>
<tr>
<td>Vascular</td>
<td>309 (5.49%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Total no of surgeries</td>
<td>9577 (13.92%)</td>
<td>11599 (16.86%)</td>
<td>13074 (19.00%)</td>
<td>15915 (23.13%)</td>
<td>18640 (27.09%)</td>
<td>68805</td>
</tr>
<tr>
<td>Mean crude mortality within 30 days postoperatively</td>
<td>88 (0.92%)</td>
<td>102 (0.88%)</td>
<td>89 (0.68%)</td>
<td>74 (0.46%)</td>
<td>92 (0.49%)</td>
<td>445 (0.65%)</td>
</tr>
<tr>
<td>Mean crude mortality within 1 year postoperatively</td>
<td>549 (5.73%)</td>
<td>656 (5.66%)</td>
<td>666 (5.09%)</td>
<td>699 (4.39%)</td>
<td>680 (3.65%)</td>
<td>3250 (4.72%)</td>
</tr>
<tr>
<td>Age (years) (Median (IQR))</td>
<td>51.89 (37.41, 68.48)</td>
<td>52.05 (37.60, 68.70)</td>
<td>53.33 (38.86, 68.70)</td>
<td>51.48 (36.66, 67.09)</td>
<td>51.30 (36.33, 66.53)</td>
<td>51.91 (37.27, 67.70)</td>
</tr>
<tr>
<td>Male sex</td>
<td>5325 (44.40%)</td>
<td>6659 (42.59%)</td>
<td>7438 (43.11%)</td>
<td>9491 (40.36%)</td>
<td>11244 (39.68%)</td>
<td>40157 (41.64%)</td>
</tr>
<tr>
<td>Non-European ethnicity (% of those with known ethnicity)</td>
<td>3371 (35.20%)</td>
<td>4101 (35.36%)</td>
<td>4754 (36.36%)</td>
<td>5880 (36.95%)</td>
<td>7109 (38.14%)</td>
<td>25215 (36.65%)</td>
</tr>
<tr>
<td>ASA score ≥3</td>
<td>2040 (21.30%)</td>
<td>2712 (23.38%)</td>
<td>3329 (28.09%)</td>
<td>3737 (26.42%)</td>
<td>4108 (25.04%)</td>
<td>15926 (25.05%)</td>
</tr>
<tr>
<td>Grade of surgery, intermediate or major</td>
<td>6693 (69.89%)</td>
<td>7718 (66.54%)</td>
<td>8641 (66.09%)</td>
<td>10240 (64.34%)</td>
<td>11586 (62.16%)</td>
<td>44878 (65.22%)</td>
</tr>
<tr>
<td>Surgical specialty</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>General surgery</td>
<td>2276 (23.77%)</td>
<td>2551 (21.99%)</td>
<td>3392 (25.94%)</td>
<td>3770 (23.69%)</td>
<td>5049 (27.09%)</td>
<td>17038 (24.76%)</td>
</tr>
<tr>
<td>Gynaecology</td>
<td>2181 (22.77%)</td>
<td>2773 (23.91%)</td>
<td>2988 (22.85%)</td>
<td>4256 (26.74%)</td>
<td>5030 (26.98%)</td>
<td>17228 (25.04%)</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>922 (9.63%)</td>
<td>1092 (9.41%)</td>
<td>908 (6.95%)</td>
<td>917 (5.76%)</td>
<td>987 (5.30%)</td>
<td>4826 (7.01%)</td>
</tr>
<tr>
<td>Orthopaedics</td>
<td>536 (5.60%)</td>
<td>1081 (9.32%)</td>
<td>1525 (11.66%)</td>
<td>1893 (11.89%)</td>
<td>1854 (9.95%)</td>
<td>6889 (10.01%)</td>
</tr>
<tr>
<td>Otorhinolaryngology</td>
<td>1211 (12.64%)</td>
<td>1665 (14.35%)</td>
<td>1745 (13.35%)</td>
<td>1653 (10.39%)</td>
<td>2260 (12.12%)</td>
<td>8534 (12.40%)</td>
</tr>
<tr>
<td>Urology</td>
<td>1838 (19.19%)</td>
<td>1829 (15.77%)</td>
<td>1918 (14.67%)</td>
<td>2148 (13.50%)</td>
<td>2184 (11.72%)</td>
<td>9917 (14.41%)</td>
</tr>
<tr>
<td>Vascular</td>
<td>613 (6.40%)</td>
<td>608 (5.24%)</td>
<td>598 (4.57%)</td>
<td>1278 (8.03%)</td>
<td>1276 (6.85%)</td>
<td>4373 (6.36%)</td>
</tr>
</tbody>
</table>
Thirty-day mortality by age and by ASA score is depicted in Figures 43 and 44, respectively. During 2002–2012, mortality after non-cardiac surgery was relatively infrequent amongst patients with an ASA score of 1 or 2, irrespective of whether their surgery was emergent or scheduled. For patients with an ASA score of 3 or more, mortality rates increased with each increase in ASA score. Perioperative mortality was highest for emergency surgeries within each ASA category. Note that the sample sizes were small for elective surgeries with an ASA score of 5 (6 surgeries) (Figure 43).

**Figure 43.** Thirty-day mortality following non-cardiac surgery by ASA score and surgery type, Auckland City Hospital, 2002–2012.

Mortality following emergency surgery during 2002–2012 was relatively infrequent amongst patients aged under 60 years, but rose thereafter (Figure 44). For patients aged 60+ years, mortality rates increased with increasing age, with the highest rates observed among patients aged 90 years and over. Compared with emergency surgery, mortality following elective surgery was infrequent at all ages. Mortality rates for elective surgery increased for those aged 70+ years, but remained lower than for emergency surgery at all ages from 60 years onwards.
Logistic regression analysis was performed to examine the impact of patient- and surgery-specific factors on 30-day perioperative mortality for patients undergoing non-cardiac surgery. The results of the regression analysis for combined emergency and elective surgeries are presented in Table 35. During 2010–2012, mortality following emergency or elective surgery was significantly higher for patients aged 60+ years (vs 16–59 years) and for patients with ASA scores of 2, 3, 4 or 5 (vs ASA score of 1). These differences remained after the risk was adjusted for patient factors including age, gender, ethnicity and ASA score. No significant differences were observed by ethnicity or sex in the multivariable regression model. With respect to the surgery-specific factors, mortality was significantly higher for gynaecological and neurosurgery (vs general surgery), for emergency (vs elective) surgery and for major (vs minor) surgery. No significant differences were observed for duration of surgery.

During the same period, mortality following emergency non-cardiac surgery was significantly higher for patients aged 60+ years (vs 16–59 years) and for patients with ASA scores of 2, 3, 4 or 5 (vs ASA score of 1) (Table 36). These differences remained after the risk was adjusted for patient factors including age, gender, ethnicity and ASA score. No significant differences were observed by ethnicity or sex in the multivariable regression model. With respect to the surgery-specific factors, mortality was significantly higher for neurosurgery (vs general surgery) and major (vs minor) surgery. No significant differences were evident for duration of surgery. The same variables were significant following elective non-cardiac surgery.
Mortality following elective surgery was significantly higher for patients aged 60+ years (vs 16–59 years) and for patients with ASA scores of 2, 3, 4 or 5 (vs ASA score of 1), even after the risk was adjusted for patient factors including age, gender, ethnicity and ASA score (Table 37). No significant differences were observed by ethnicity or sex in the multivariable regression model.
Table 35. Postoperative mortality according to patient- and surgery-related characteristics of the study population for combined emergency and elective surgeries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All surgeries (n=104,699 from 85,373 patients)</th>
<th>Death within 30 days (n=1,581)</th>
<th>No death within 30 days (n=103,118)</th>
<th>Unadjusted odds ratio [95% CI]</th>
<th>Adjusted odds ratio [95% CI]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/11/2002–31/10/2004</td>
<td>15209 (14.53%)</td>
<td>306 (2.01%)</td>
<td>14903 (97.99%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2004–31/10/2006</td>
<td>18667 (17.83%)</td>
<td>361 (1.93%)</td>
<td>18306 (98.07%)</td>
<td>0.96 [0.82, 1.12]</td>
<td>0.81 [0.68, 0.95]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2006–31/10/2008</td>
<td>20302 (19.39%)</td>
<td>302 (1.49%)</td>
<td>20000 (98.51%)</td>
<td>0.74 [0.63, 0.86]</td>
<td>0.63 [0.53, 0.75]</td>
<td>.0122</td>
</tr>
<tr>
<td>1/11/2008–31/10/2010</td>
<td>23481 (22.43%)</td>
<td>284 (1.21%)</td>
<td>23197 (98.79%)</td>
<td>0.60 [0.51, 0.70]</td>
<td>0.58 [0.49, 0.69]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2010–31/10/2012</td>
<td>27040 (25.83%)</td>
<td>328 (1.21%)</td>
<td>26712 (98.79%)</td>
<td>0.60 [0.51, 0.70]</td>
<td>0.63 [0.53, 0.75]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Age (years)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16–59</td>
<td>66386 (63.41%)</td>
<td>414 (0.62%)</td>
<td>65972 (99.38%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>60–69</td>
<td>15082 (14.41%)</td>
<td>267 (1.77%)</td>
<td>14815 (98.23%)</td>
<td>2.87 [2.46, 3.35]</td>
<td>1.63 [1.37, 1.93]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>70–79</td>
<td>12877 (12.30%)</td>
<td>382 (2.97%)</td>
<td>12495 (97.03%)</td>
<td>4.87 [4.23, 5.61]</td>
<td>2.17 [1.84, 2.56]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>80–89</td>
<td>8637 (8.25%)</td>
<td>404 (4.68%)</td>
<td>8233 (95.32%)</td>
<td>7.82 [6.80, 8.99]</td>
<td>2.95 [2.48, 3.50]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>90 and over</td>
<td>1717 (1.64%)</td>
<td>114 (6.64%)</td>
<td>1603 (93.36%)</td>
<td>11.33 [9.12, 13.97]</td>
<td>3.27 [2.53, 4.21]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>47933 (45.78%)</td>
<td>798 (1.66%)</td>
<td>47135 (98.34%)</td>
<td>Reference</td>
<td>Reference</td>
<td>0.2285</td>
</tr>
<tr>
<td>Female</td>
<td>56766 (54.22%)</td>
<td>783 (1.38%)</td>
<td>55983 (98.62%)</td>
<td>0.83 [0.75, 0.91]</td>
<td>1.07 [0.96, 1.20]</td>
<td></td>
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<tr>
<td>Ethnicity</td>
<td></td>
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</tr>
<tr>
<td>European</td>
<td>66602 (63.61%)</td>
<td>1151 (1.73%)</td>
<td>65451 (98.27%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Māori</td>
<td>11372 (10.86%)</td>
<td>183 (1.61%)</td>
<td>11189 (98.39%)</td>
<td>0.93 [0.58, 1.50]</td>
<td>1.03 [0.85, 1.20]</td>
<td>0.7877</td>
</tr>
<tr>
<td>Pacific</td>
<td>9613 (9.18%)</td>
<td>115 (1.20%)</td>
<td>9498 (98.80%)</td>
<td>0.71 [0.43, 1.15]</td>
<td>0.99 [0.80, 1.23]</td>
<td>0.9435</td>
</tr>
<tr>
<td>Other</td>
<td>16318 (15.59%)</td>
<td>113 (0.69%)</td>
<td>16205 (99.31%)</td>
<td>0.38 [0.24, 0.63]</td>
<td>0.85 [0.68, 1.04]</td>
<td>0.1224</td>
</tr>
<tr>
<td>Unknown</td>
<td>794 (0.76%)</td>
<td>19 (2.39%)</td>
<td>775 (97.61%)</td>
<td>1.31 [0.83, 2.08]</td>
<td>1.23 [0.72, 1.99]</td>
<td>0.4178</td>
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<td>ASA score</td>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td>35785 (34.18%)</td>
<td>58 (0.16%)</td>
<td>35727 (99.84%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>2</td>
<td>36227 (34.60%)</td>
<td>163 (0.45%)</td>
<td>36064 (99.55%)</td>
<td>2.78 [2.08, 3.79]</td>
<td>2.13 [1.58, 2.92]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>3</td>
<td>23028 (21.99%)</td>
<td>626 (2.72%)</td>
<td>22402 (97.28%)</td>
<td>17.21 [13.27, 22.78]</td>
<td>7.96 [6.02, 10.72]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>4</td>
<td>4016 (3.84%)</td>
<td>615 (15.31%)</td>
<td>3401 (84.69%)</td>
<td>111.39 [85.70, 147.65]</td>
<td>33.78 [25.38, 45.71]</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

202
Table 35 (continued). Postoperative mortality according to patient- and surgery-related characteristics of the study population for combined emergency and elective surgeries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All surgeries (n=104,699 from 85,373 patients)</th>
<th>Death within 30 days (n=1,581)</th>
<th>No death within 30 days (n=103,118)</th>
<th>Unadjusted odds ratio [95% CI]</th>
<th>Adjusted odds ratio [95% CI]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 missing</td>
<td>199 (0.19%)</td>
<td>101 (50.75%)</td>
<td>98 (49.25%)</td>
<td>634.84 [436.68, 932.60]</td>
<td>137.99 [92.13, 208.51]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Grade of surgery</td>
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</tr>
<tr>
<td>Minor</td>
<td>35591 (33.99%)</td>
<td>273 (0.77%)</td>
<td>35318 (99.23%)</td>
<td>Reference</td>
<td>Reference</td>
<td>0.1983</td>
</tr>
<tr>
<td>Intermediate</td>
<td>50527 (48.26%)</td>
<td>591 (1.17%)</td>
<td>49936 (98.83%)</td>
<td>1.53 [1.33, 1.77]</td>
<td>0.90 [0.77, 1.06]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Major</td>
<td>18581 (17.75%)</td>
<td>717 (3.86%)</td>
<td>17864 (96.14%)</td>
<td>5.19 [4.52, 5.98]</td>
<td>1.92 [1.60, 2.31]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Duration of surgery</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Less than 2 hours</td>
<td>85683 (81.84%)</td>
<td>1120 (1.31%)</td>
<td>84563 (98.69%)</td>
<td>Reference</td>
<td>Reference</td>
<td>0.9264</td>
</tr>
<tr>
<td>2 hours or greater</td>
<td>19016 (18.16%)</td>
<td>461 (2.42%)</td>
<td>18555 (97.58%)</td>
<td>1.84 [1.65, 2.99]</td>
<td>1.01 [0.87, 1.16]</td>
<td></td>
</tr>
<tr>
<td>Admission type</td>
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<td></td>
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</tr>
<tr>
<td>Elective</td>
<td>68805 (65.72%)</td>
<td>445 (0.65%)</td>
<td>68360 (99.35%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Emergency</td>
<td>35894 (34.28%)</td>
<td>1136 (3.16%)</td>
<td>34758 (96.84%)</td>
<td>5.02 [4.50, 5.61]</td>
<td>3.22 [2.82, 3.68]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Surgical specialty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General surgery</td>
<td>28825 (27.53%)</td>
<td>421 (1.46%)</td>
<td>28404 (98.54%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Gynaecology</td>
<td>18179 (17.36%)</td>
<td>25 (0.14%)</td>
<td>18154 (99.86%)</td>
<td>0.09 [0.06, 0.14]</td>
<td>0.43 [0.28, 0.65]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>6888 (6.58%)</td>
<td>352 (5.11%)</td>
<td>6536 (94.89%)</td>
<td>3.63 [3.14, 4.20]</td>
<td>2.41 [2.04, 2.85]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Orthopaedics</td>
<td>21489 (20.52%)</td>
<td>378 (1.76%)</td>
<td>21111 (98.24%)</td>
<td>1.21 [1.05, 1.39]</td>
<td>0.85 [0.72, 1.01]</td>
<td>.0653</td>
</tr>
<tr>
<td>Otorhinolaryngology</td>
<td>9829 (9.39%)</td>
<td>69 (0.70%)</td>
<td>9760 (99.30%)</td>
<td>0.48 [0.37, 0.61]</td>
<td>1.09 [0.82, 1.43]</td>
<td>.5596</td>
</tr>
<tr>
<td>Urology</td>
<td>13169 (12.58%)</td>
<td>105 (0.80%)</td>
<td>13064 (99.20%)</td>
<td>0.54 [0.44, 0.67]</td>
<td>0.83 [0.66, 1.05]</td>
<td>.1300</td>
</tr>
<tr>
<td>Vascular</td>
<td>6320 (6.04%)</td>
<td>231 (3.66%)</td>
<td>6089 (96.34%)</td>
<td>2.56 [2.17, 3.01]</td>
<td>0.92 [0.77, 1.10]</td>
<td>.3625</td>
</tr>
</tbody>
</table>
Table 36. Postoperative mortality according to patient- and surgery-related characteristics of the study population for emergency surgeries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All surgeries (n=35,894 from 33,611 patients)</th>
<th>Death within 30 days (n=1,136)</th>
<th>No death within 30 days (n=34,758)</th>
<th>Unadjusted odds ratio [95% CI]</th>
<th>Adjusted odds ratio [95% CI]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/11/2002–31/10/2004</td>
<td>5632 (15.69%)</td>
<td>218 (3.87%)</td>
<td>5414 (96.13%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>1/11/2004–31/10/2006</td>
<td>7068 (19.69%)</td>
<td>259 (3.66%)</td>
<td>6809 (96.34%)</td>
<td>0.94 [0.79, 1.14]</td>
<td>0.78 [0.63, 0.95]</td>
<td>0.0138</td>
</tr>
<tr>
<td>1/11/2006–31/10/2008</td>
<td>7228 (20.14%)</td>
<td>213 (2.95%)</td>
<td>7015 (97.05%)</td>
<td>0.75 [0.62, 0.91]</td>
<td>0.59 [0.48, 0.73]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2008–31/10/2010</td>
<td>7566 (21.08%)</td>
<td>210 (2.78%)</td>
<td>7356 (97.22%)</td>
<td>0.71 [0.58, 0.86]</td>
<td>0.59 [0.48, 0.73]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2010–31/10/2012</td>
<td>8400 (23.40%)</td>
<td>236 (2.81%)</td>
<td>8164 (97.19%)</td>
<td>0.72 [0.60, 0.87]</td>
<td>0.64 [0.52, 0.79]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Age (years)</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>16–59</td>
<td>23302 (64.92%)</td>
<td>304 (1.30%)</td>
<td>22998 (98.70%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>60–69</td>
<td>4135 (11.52%)</td>
<td>181 (4.38%)</td>
<td>3954 (95.62%)</td>
<td>3.46 [2.87, 4.17]</td>
<td>1.63 [1.32, 2.00]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>70–79</td>
<td>3730 (10.39%)</td>
<td>246 (6.60%)</td>
<td>3484 (93.40%)</td>
<td>5.34 [4.50, 6.34]</td>
<td>1.87 [1.53, 2.29]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>80–89</td>
<td>3672 (10.23%)</td>
<td>305 (8.31%)</td>
<td>3367 (91.69%)</td>
<td>6.85 [5.82, 8.07]</td>
<td>2.56 [2.08, 3.15]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>90 and over</td>
<td>1055 (2.94%)</td>
<td>100 (9.48%)</td>
<td>955 (90.52%)</td>
<td>7.92 [6.24, 9.98]</td>
<td>2.81 [2.10, 3.74]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>19285 (53.73%)</td>
<td>558 (2.89%)</td>
<td>18727 (97.11%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
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<tr>
<td>Female</td>
<td>16609 (46.27%)</td>
<td>578 (3.48%)</td>
<td>16031 (96.52%)</td>
<td>1.21 [1.08, 1.36]</td>
<td>1.12 [0.98, 1.28]</td>
<td>.1062</td>
</tr>
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<td>Ethnicity</td>
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<td></td>
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<td></td>
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<tr>
<td>European</td>
<td>23012 (64.11%)</td>
<td>810 (3.52%)</td>
<td>22202 (96.48%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Māori</td>
<td>4030 (11.23%)</td>
<td>139 (3.45%)</td>
<td>3891 (96.55%)</td>
<td>1.14 [0.81, 1.17]</td>
<td>1.07 [0.86, 1.33]</td>
<td>.5144</td>
</tr>
<tr>
<td>Pacific</td>
<td>3427 (9.55%)</td>
<td>87 (2.54%)</td>
<td>3340 (97.46%)</td>
<td>0.98 [0.57, 0.89]</td>
<td>1.01 [0.79, 1.30]</td>
<td>.9076</td>
</tr>
<tr>
<td>Other</td>
<td>5100 (14.21%)</td>
<td>87 (1.71%)</td>
<td>5013 (98.29%)</td>
<td>0.48 [0.38, 0.59]</td>
<td>0.92 [0.71, 1.16]</td>
<td>.4804</td>
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<td>Unknown</td>
<td>325 (0.91%)</td>
<td>13 (4.00%)</td>
<td>312 (96.00%)</td>
<td>0.71 [0.62, 1.92]</td>
<td>1.34 [0.68, 2.42]</td>
<td>.3672</td>
</tr>
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<td>ASA score</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>13868 (38.87%)</td>
<td>41 (0.30%)</td>
<td>13827 (99.70%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10489 (29.40%)</td>
<td>75 (0.72%)</td>
<td>10414 (99.28%)</td>
<td>2.43 [1.67, 3.59]</td>
<td>1.77 [1.21, 2.64]</td>
<td>.0039</td>
</tr>
<tr>
<td>3</td>
<td>8459 (23.71%)</td>
<td>388 (4.59%)</td>
<td>8071 (95.41%)</td>
<td>16.21 [11.89, 22.73]</td>
<td>8.12 [5.81, 11.64]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>4</td>
<td>2665 (7.47%)</td>
<td>522 (19.59%)</td>
<td>2143 (80.41%)</td>
<td>85.15 [60.38, 114.96]</td>
<td>35.65 [25.42, 51.20]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>5</td>
<td>193 (0.54%)</td>
<td>100 (51.81%)</td>
<td>93 (48.19%)</td>
<td>362.63 [240.94, 555.33]</td>
<td>145.06 [93.31, 228.82]</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Table 36 (continued). Postoperative mortality according to patient- and surgery-related characteristics of the study population for emergency surgeries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All surgeries (n=35,894 from 33,611 patients)</th>
<th>Death within 30 days (n=1,136)</th>
<th>No death within 30 days (n=34,758)</th>
<th>Unadjusted odds ratio [95% CI]</th>
<th>Adjusted odds ratio [95% CI]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td>12.98 [5.98, 25.72]</td>
<td>&lt;.0001</td>
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</tr>
<tr>
<td>Grade of surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>11664 (32.50%)</td>
<td>193 (1.65%)</td>
<td>11471 (98.35%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Intermediate</td>
<td>19688 (54.85%)</td>
<td>481 (2.44%)</td>
<td>19207 (97.56%)</td>
<td>1.49 [1.26, 1.77]</td>
<td>0.99 [0.82, 1.20]</td>
<td>.9172</td>
</tr>
<tr>
<td>Major</td>
<td>4542 (12.65%)</td>
<td>462 (10.17%)</td>
<td>4080 (89.83%)</td>
<td>6.73 [5.68, 8.01]</td>
<td>1.93 [1.55, 2.42]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Duration of surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 2 hours</td>
<td>31363 (87.38%)</td>
<td>878 (2.80%)</td>
<td>30485 (97.20%)</td>
<td>Reference</td>
<td>Reference</td>
<td>.8714</td>
</tr>
<tr>
<td>2 hours or greater</td>
<td>4531 (12.62%)</td>
<td>258 (5.69%)</td>
<td>4273 (94.31%)</td>
<td>2.10 [1.81, 2.41]</td>
<td>0.99 [0.82, 1.18]</td>
<td></td>
</tr>
<tr>
<td>Surgical specialty</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General surgery</td>
<td>11787 (32.84%)</td>
<td>312 (2.65%)</td>
<td>11475 (97.35%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Gynaecology</td>
<td>951 (2.65%)</td>
<td>3 (0.32%)</td>
<td>948 (99.68%)</td>
<td>0.12 [0.03, 0.30]</td>
<td>0.32 [0.08, 0.88]</td>
<td>.0580</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>2062 (5.74%)</td>
<td>220 (10.67%)</td>
<td>1842 (89.33%)</td>
<td>4.39 [3.67, 5.25]</td>
<td>2.07 [1.68, 2.56]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Orthopaedics</td>
<td>14600 (40.67%)</td>
<td>350 (24.0%)</td>
<td>14250 (97.60%)</td>
<td>0.90 [0.77, 1.05]</td>
<td>0.88 [0.73, 1.07]</td>
<td>.1902</td>
</tr>
<tr>
<td>Otorhinolaryngology</td>
<td>1295 (3.61%)</td>
<td>26 (2.01%)</td>
<td>1269 (97.99%)</td>
<td>0.75 [0.49, 1.11]</td>
<td>0.97 [0.61, 1.48]</td>
<td>.8819</td>
</tr>
<tr>
<td>Urology</td>
<td>3252 (9.06%)</td>
<td>66 (2.03%)</td>
<td>3186 (97.97%)</td>
<td>0.76 [0.58, 0.99]</td>
<td>1.12 [0.82, 1.50]</td>
<td>.4644</td>
</tr>
<tr>
<td>Vascular</td>
<td>1947 (5.42%)</td>
<td>159 (8.17%)</td>
<td>1788 (91.83%)</td>
<td>3.27 [2.68, 3.98]</td>
<td>0.97 [0.78, 1.21]</td>
<td>.7923</td>
</tr>
</tbody>
</table>
Table 37. Postoperative mortality according to patient- and surgery-related characteristics of the study population for elective surgeries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Surgeries (n=68805 from 56702 patients)</th>
<th>Death within 30 Days (n=445)</th>
<th>No Death within 30 Days (n=68360)</th>
<th>Unadjusted Odds Ratio [95% CI]</th>
<th>Adjusted Odds Ratio [95% CI]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/11/2002–31/10/2004</td>
<td>9577 (13.92%)</td>
<td>88 (0.92%)</td>
<td>9489 (99.08%)</td>
<td>Reference</td>
<td>Reference</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2004–31/10/2006</td>
<td>11599 (16.86%)</td>
<td>102 (0.88%)</td>
<td>11497 (99.12%)</td>
<td>0.96 [0.72, 1.28]</td>
<td>0.88 [0.65, 1.18]</td>
<td>.3805</td>
</tr>
<tr>
<td>1/11/2006–31/10/2008</td>
<td>13074 (19.00%)</td>
<td>89 (0.68%)</td>
<td>12985 (99.32%)</td>
<td>0.74 [0.55, 0.99]</td>
<td>0.68 [0.50, 0.92]</td>
<td>.0133</td>
</tr>
<tr>
<td>1/11/2008–31/10/2010</td>
<td>15915 (23.13%)</td>
<td>74 (0.46%)</td>
<td>15841 (99.54%)</td>
<td>0.50 [0.37, 0.69]</td>
<td>0.54 [0.39, 0.75]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>1/11/2010–31/10/2012</td>
<td>18640 (27.09%)</td>
<td>92 (0.49%)</td>
<td>18548 (99.51%)</td>
<td>0.53 [0.40, 0.72]</td>
<td>0.60 [0.44, 0.82]</td>
<td>.0002</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16–59</td>
<td>43084 (62.62%)</td>
<td>110 (0.26%)</td>
<td>42974 (99.74%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>60–69</td>
<td>10947 (15.91%)</td>
<td>86 (0.79%)</td>
<td>10861 (99.21%)</td>
<td>3.09 [2.33, 4.10]</td>
<td>1.65 [1.23, 2.22]</td>
<td>.0009</td>
</tr>
<tr>
<td>70–79</td>
<td>9147 (13.29%)</td>
<td>136 (1.49%)</td>
<td>9011 (98.51%)</td>
<td>5.90 [4.58, 7.60]</td>
<td>2.83 [2.14, 3.75]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>80–89</td>
<td>4965 (7.22%)</td>
<td>99 (1.99%)</td>
<td>4866 (98.01%)</td>
<td>7.95 [6.04, 10.44]</td>
<td>3.95 [2.88, 5.42]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>90 and over</td>
<td>662 (0.96%)</td>
<td>14 (2.11%)</td>
<td>648 (97.89%)</td>
<td>8.44 [6.41, 14.29]</td>
<td>4.42 [2.33, 7.84]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Male</td>
<td>28648 (41.64%)</td>
<td>240 (0.84%)</td>
<td>28408 (99.16%)</td>
<td>Reference</td>
<td>Reference</td>
<td>.5997</td>
</tr>
<tr>
<td>Female</td>
<td>40157 (58.36%)</td>
<td>205 (0.51%)</td>
<td>39952 (99.50%)</td>
<td>0.61 [0.50, 0.73]</td>
<td>0.95 [0.77, 1.16]</td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>43590 (63.35%)</td>
<td>341 (0.78%)</td>
<td>43249 (99.22%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Māori</td>
<td>7342 (10.67%)</td>
<td>44 (0.60%)</td>
<td>7298 (99.40%)</td>
<td>0.76 [0.55, 1.04]</td>
<td>0.96 [0.68, 1.34]</td>
<td>.8326</td>
</tr>
<tr>
<td>Pacific</td>
<td>6186 (8.99%)</td>
<td>28 (0.45%)</td>
<td>6158 (99.55%)</td>
<td>0.58 [0.39, 0.92]</td>
<td>0.96 [0.63, 1.41]</td>
<td>.8337</td>
</tr>
<tr>
<td>Other</td>
<td>11218 (16.30%)</td>
<td>26 (0.23%)</td>
<td>11192 (99.77%)</td>
<td>0.29 [0.19, 0.43]</td>
<td>0.73 [0.47, 1.07]</td>
<td>.1250</td>
</tr>
<tr>
<td>Unknown</td>
<td>469 (0.68%)</td>
<td>6 (1.28%)</td>
<td>463 (98.72%)</td>
<td>1.64 [0.65, 3.38]</td>
<td>1.09 [0.42, 2.34]</td>
<td>.8372</td>
</tr>
<tr>
<td><strong>ASA score</strong></td>
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</tr>
<tr>
<td>1</td>
<td>21917 (34.47%)</td>
<td>17 (0.8%)</td>
<td>21900 (99.92%)</td>
<td>Reference</td>
<td>Reference</td>
<td>.0002</td>
</tr>
<tr>
<td>2</td>
<td>25738 (40.48%)</td>
<td>88 (0.34%)</td>
<td>25650 (99.66%)</td>
<td>4.42 [2.70, 7.69]</td>
<td>2.77 [1.67, 4.88]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>3</td>
<td>14569 (22.91%)</td>
<td>238 (1.63%)</td>
<td>14331 (98.37%)</td>
<td>21.39 [13.50, 36.37]</td>
<td>8.44 [5.15, 14.71]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>4</td>
<td>1351 (2.12%)</td>
<td>93 (6.88%)</td>
<td>1258 (93.12%)</td>
<td>95.24 [58.18, 165.74]</td>
<td>33.98 [20.05, 60.81]</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>5</td>
<td>6 (0.01%)</td>
<td>1 (16.67%)</td>
<td>5 (83.33%)</td>
<td>257.65 [13.09, 1713.35]</td>
<td>99.28 [4.87, 726.95]</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Table 37 (continued). Postoperative mortality according to patient- and surgery-related characteristics of the study population for elective surgeries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Surgeries (n=68805 from 56702 patients)</th>
<th>Death within 30 Days (n=445)</th>
<th>No Death within 30 Days (n=68360)</th>
<th>Unadjusted Odds Ratio [95% CI]</th>
<th>Adjusted Odds Ratio [95% CI]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing</td>
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<td></td>
<td></td>
<td>1.73 [0.69, 4.03]</td>
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<td>.2157</td>
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<td>Grade of surgery</td>
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<td></td>
</tr>
<tr>
<td>Minor</td>
<td>23927 (34.78%)</td>
<td>80 (0.33%)</td>
<td>23847 (99.67%)</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>30839 (44.82%)</td>
<td>110 (0.36%)</td>
<td>30729 (99.64%)</td>
<td>1.07 [0.80, 1.43]</td>
<td>0.85 [0.63, 1.17]</td>
<td>.3142</td>
</tr>
<tr>
<td>Major</td>
<td>14039 (20.40%)</td>
<td>255 (1.82%)</td>
<td>13784 (98.18%)</td>
<td>5.51 [4.31, 7.14]</td>
<td>1.94 [1.38, 2.73]</td>
<td>.0001</td>
</tr>
<tr>
<td>Duration of surgery</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Less than 2 hours</td>
<td>54320 (78.95%)</td>
<td>242 (0.45%)</td>
<td>54078 (99.55%)</td>
<td>Reference</td>
<td>Reference</td>
<td>.9934</td>
</tr>
<tr>
<td>2 hours or greater</td>
<td>14485 (21.05%)</td>
<td>203 (1.40%)</td>
<td>14282 (98.60%)</td>
<td>3.18 [2.63, 3.83]</td>
<td>1.00 [0.79, 1.27]</td>
<td></td>
</tr>
<tr>
<td>Surgical specialty</td>
<td></td>
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<tr>
<td>General surgery</td>
<td>17038 (24.76%)</td>
<td>109 (0.64%)</td>
<td>16929 (99.36%)</td>
<td>Reference</td>
<td>Reference</td>
<td>.0040</td>
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<td>Gynaecology</td>
<td>17228 (25.04%)</td>
<td>22 (0.13%)</td>
<td>17206 (99.87%)</td>
<td>0.20 [0.12, 0.31]</td>
<td>0.49 [0.30, 0.78]</td>
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<tr>
<td>Neurosurgery</td>
<td>4826 (7.01%)</td>
<td>132 (2.74%)</td>
<td>4694 (97.26%)</td>
<td>4.37 [3.38, 5.65]</td>
<td>2.78 [2.08, 3.73]</td>
<td>&lt;.0001</td>
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<tr>
<td>Orthopaedics</td>
<td>6889 (10.01%)</td>
<td>28 (0.41%)</td>
<td>6861 (99.59%)</td>
<td>0.63 [0.41, 0.95]</td>
<td>0.63 [0.40, 0.96]</td>
<td>.0362</td>
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<td>Otorhinolaryngology</td>
<td>8534 (12.40%)</td>
<td>43 (0.50%)</td>
<td>8491 (99.50%)</td>
<td>0.79 [0.55, 1.11]</td>
<td>1.10 [0.75, 1.60]</td>
<td>.6219</td>
</tr>
<tr>
<td>Urology</td>
<td>9917 (14.41%)</td>
<td>39 (0.39%)</td>
<td>9878 (99.61%)</td>
<td>0.61 [0.42, 0.88]</td>
<td>0.52 [0.35, 0.76]</td>
<td>.0009</td>
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<tr>
<td>Vascular</td>
<td>4373 (6.36%)</td>
<td>72 (1.65%)</td>
<td>4301 (98.35%)</td>
<td>2.60 [1.92, 3.50]</td>
<td>0.77 [0.56, 1.07]</td>
<td>.1187</td>
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6.5 Discussion

The present study was undertaken to address the third objective of this thesis: to describe 30-day and 1-year mortality for adult patients undergoing non-cardiac surgery at Auckland City Hospital between November 2002 and October 2012. Overall, 1.51% of patients died within 30 days of undergoing non-cardiac surgery during the study period, which is generally consistent with perioperative mortality rates in other reports. Meanwhile, 6.22% of patients died within 1 year of undergoing non-cardiac surgery during the study period, which suggests that most operative mortality occurs beyond 30 days. Higher 30-day mortality rates were consistently associated with increasing age, poorer overall health status indicated by ASA score, and emergency surgery. Emergency surgeries generally had higher 30-day mortality rates within each age group and ASA score compared with elective surgeries. Thirty-day mortality following elective or emergency surgery was significantly higher for patients with an ASA score of 2, 3, 4, or 5 compared with ASA score 1; those aged over 60 years compared with patients aged between 16 and 59 years; those undergoing intermediate or major surgery compared with minor surgery; and emergency surgery compared with elective surgery.

The strengths of this study lie in its use of data that are gathered directly from the patient care environment to gain valuable insight into 30-day and 1-year mortality for adult patients undergoing non-cardiac surgery at Auckland City Hospital. First, these data reflect everyday clinical practice in large, unselected patient groups and are collected in ignorance of the outcome of interest [397, 398]. For this reason, studies using RCD are likely to yield findings which are relevant on all levels – geographically, institutionally and demographically – to the anaesthetists’ own clinical settings. Second, the findings are more likely to be timely because, for the most part, data are already available. The structures for data collection already exist so the approach is unobtrusive and is not wholly constrained by data collection and cleansing processes that are performed by other organisations external to the institution. This means that RCD are especially cost-effective for the study of rare or time-delayed outcomes, such as perioperative mortality, that require data collection over a prolonged period of time [396].

The strengths of this study are tempered by its shortcomings, however. The first of these is apparent in the use of the ASA score as a summary measure of baseline patient risk. The ASA score is a measure of the overall health status of the patient before surgery and has long been used to assess perioperative risk [20, 21]. However, the objectivity of the score has been called into question [187, 193, 194] and therefore ASA status has not been included in the POSSUM score [176]. Despite this, the score is highly correlated with other preoperative risk
factors and has been shown to be highly predictive of perioperative outcomes. For example, anaesthetists’ assigned ASA scores were shown to correlate strongly with predictions of ASA score using NSQIP risk factors [759], further demonstrating a degree of objectivity of the score. The ASA score also confers the advantage of being easily determined preoperatively without the need for additional preoperative tests.

The grading of surgery as being low-, intermediate- or high-risk was determined based solely on clinical judgement and this could be considered a limitation. Procedure casemix is known to influence perioperative mortality, so that the intrinsic risk of an abdominal aortic aneurysm repair, for example, is greater than the risk of breast surgery [760]. However, the relative weightings of surgical procedures are not known [760]. We assigned specific procedures to risk categories based on expert opinion in keeping with risk scores such as RCRI [36, 174, 176]. Alternative, data-driven approaches do exist (see Glance [173]), but are likely to be of limited use at individual hospitals owing to small sample sizes.

Finally, we used surgeries rather than admissions as the unit of analysis. However, the difference between the two approaches appears to be small. Ariyaratnam et al. [760] found that although perioperative mortality varied significantly when procedures compared with admissions were used as the denominator for patients undergoing surgery in Geelong and Port Moresby, perioperative mortality in NZ was 0.56 per 100 procedures compared with 0.60 per 100 admissions nationwide. The authors attribute this difference to variation in what constitutes a surgical procedure, evidenced by a decrease in the difference between estimates from the two approaches after line insertions and endoscopy were removed. This finding highlights the need for robust data linkage with unique identifiers for patients, procedures and admissions, which we made use of for this study.

Notwithstanding the challenges of comparing perioperative mortality at Auckland City Hospital with published studies, our findings are generally consistent with the available literature. The 30-day mortality rate in patients undergoing non-cardiac surgery can be substantial and has been reported in the range of 0.5% at 48 hours [32] to 4.0% at 7 days after surgery [162]. A retrospective analysis of 363,897 patients held in the NSQIP [141, 353, 354] database from 2005 to 2007 reported an overall 30-day mortality rate of 1.76% [761]. All procedures with a median length of stay greater than 1 day and those likely to have a high mortality rate were included. Of the 6,395 deaths reported, 1,486 (23%) occurred after hospital discharge. Glance and colleagues [173] reported a similar 30-day mortality rate of 1.34% using NSQIP data for patients undergoing non-cardiac surgery during the same period. Outside of America, a review of 3.7 million surgical procedures in 102 hospitals from
national registry data in the Netherlands reported an all-cause perioperative mortality before discharge for the period 1991–2005 of 1.85% [733]. Pearse and colleagues [162] reported an in-hospital mortality rate of 4.0% following non-cardiac inpatient surgery in the European Surgical Outcomes Study (EuSOS) cohort study. Crude and adjusted mortality rates following surgery varied between countries and were higher than anticipated.

Outside of Europe and America, Ariyaratnam and colleagues [760] sought to assess perioperative mortality at hospitals across NZ, South Africa and Papua New Guinea using large, mixed surgical datasets that represented high-, middle- and low-income countries. A total of 1,362,635 patient admissions for 1,514,242 procedures that required general or neuraxial anaesthesia between 2007 and 2011 were included. Using the New Zealand National Minimum Dataset, the authors reported in-hospital perioperative mortality of 0.39 per 100 admissions and an overall perioperative mortality within 30 days of 0.60 per 100 admissions. These mortality rates are largely consistent with the findings of the latest report of the Perioperative Mortality Review Committee (POMRC). In its report, the POMRC [762] examined perioperative mortality using the New Zealand National Minimum Dataset for operations and procedures performed under general anaesthesia in public and some private hospitals during 2009–2013. There were 6,755 deaths and cumulative mortality was 0.56% of all admissions. Compared with estimates from studies across Europe, America and Australasia, 30-day mortality following non-cardiac surgery at Auckland City Hospital is generally consistent with, and in some instances lower than, international reports of perioperative mortality.

Variation in mortality rates between published literature and institution-specific mortality rates may reflect differences in volumes, casemix or selection criteria, methods of calculation and timeframes for the outcome of interest as well as data quality, accuracy and completeness. For example, mortality rates improved across both elective, emergency and combined emergency and elective surgeries over the 10-year study period, likely reflecting improved data quality, coding accuracy and wider changes to HISs and their use. Similarly, the small variation in national mortality rates described in the latest POMRC report [762] and the mortality rates reported in this study is likely to reflect differences in volumes, casemix and, perhaps most of all, the method of calculation for the outcome. The POMRC calculation included all admissions in the denominator, but only the associated death once. This approach would likely contribute to a smaller estimate of perioperative mortality. Variation in mortality rates between DHBs has also been demonstrated in other reports by the New Zealand Health Quality and Safety Commission [756]. Auckland City Hospital is the largest provider of
emergency and elective surgical services within NZ [16] and, as a quaternary hospital, is charged with providing the most specialised and complex level of medical care available in the country. Over and above the method of calculation, both of these factors are likely to have some impact on the small variation in national and institutional mortality.

We found higher 30-day mortality rates were consistently associated with increasing age, poorer overall health status indicated by ASA score, and emergency surgery. In our study, the OR for mortality increased with each age bracket beyond 69 years; the OR for 30-day mortality approximately tripled for emergency surgery compared with elective surgery; and the OR for 30-day mortality more than tripled with each increase in ASA score from ASA 2. These findings are consistent with reports from a number of published studies. In a prospective observational study of 4,158 older adults undergoing non-cardiac surgery in Australia and NZ, Story and colleagues [87] found that ASA score and preoperative albumin were associated with increased 30-day mortality. In the study, the adjusted OR for 30-day mortality increased approximately threefold with each subsequent increase in ASA status from ASA 2. In another large study of surgical patients aged 17 years and over using NSQIP data [759], ASA score alone was a strong predictor of perioperative mortality. However, preoperative NSQIP risk factors yielded better predictions of perioperative mortality when combined. Ariyaratnam and colleagues [760] reported significant, independent associations between both emergency admission and age greater than 65 years, and in-patient death using data outside of the NSQIP. In their study of 1,262,635 patients who underwent surgery in NZ, Geelong, Pietermaritzburg and Port Moresby, the odds of in-patient death were up to 9 times greater for patients aged older than 65 years compared with other ages on multivariate analysis.

Studies have also shown significant variation in perioperative mortality rates across surgical procedures [336]. Yu and colleagues [761] found that the proportion of deaths occurring post-discharge ranged from 6.3% for thoracoabdominal aneurysm repair to 50.0% for femoral-distal bypass with vein. In a large population-based study of postoperative mortality in the Netherlands [733], adjusted incidence of perioperative mortality ranged from 0.07% for patients undergoing breast surgery to 5.97% for patients undergoing vascular surgery. We found a statistically significant difference in the likelihood of postoperative death within 30 days considering surgical risk factors. Among both elective and emergency procedures, mortality was significantly higher for those undergoing intermediate-risk or high-risk procedures compared with minor procedures after adjusting for sociodemographic and clinical factors.
This study has two clear implications for practitioners. First, perioperative mortality rates for patients who underwent non-cardiac at Auckland City Hospital from November 2002 to October 2012 appear to be comparable to reports from internationally published studies. Second, despite similarity to international literature, this study suggests that RCD provide anaesthetists with a valuable source of information about the risks of anaesthesia and surgery. RCD are not redundant for the purpose of reviewing mortality after surgery. This study has shown that RCD, in the context of preoperative decision-making and planning, possess many of the attributes of quality data (see [392]). The strengths of these data, namely their quantity, objectivity, timeliness and geographic relevance, mean that they are applicable to anaesthetists’ decision-making and planning as soon as they are recorded in the EHR. As data capture continues over time, temporal trends become evident, either demonstrating year-on-year consistency or, in the case of this study, improvement over time, thereby promoting believability [392] of data. The data have near-complete demographic information, making it possible to explore associations between patient factors such as age, gender and ethnicity, and perioperative mortality. Additionally, an ASA score is available for the majority of patients, so anaesthetists can assess the risk of perioperative mortality based on the patient’s health status prior to surgery. Although information from RCD sources must be interpreted with a degree of caution, the information can be easily accessed and routinely used to help patients to come to an informed decision about surgery and anaesthesia, based on information about the day-to-day care of many similar patients who came before them. Looking forward, these data permit new thinking about risk and perioperative care, through exploration of data in different ways and preliminary hypothesis testing. Collectively, this analysis has shown that RCD can provide anaesthetists with valuable insight into the risk of perioperative mortality in terms of diverse factors related to the patient and proposed surgery.

Although this study has uncovered valuable insights into institutional perioperative mortality, important questions remain unanswered and further work is needed to address these. Comparison of 30-day and 1-year mortality suggests that most operative mortality occurs beyond 30-days after surgery. This raises questions about the duration of this outcome. In their study of adult patients undergoing major non-cardiac surgery with general anaesthesia, Monk and colleagues showed that 5.5% (58 of 1,064) patients died within 1 year of undergoing non-cardiac surgery. By comparison, the 30-day mortality rate was 0.7% (7 of 1,064). Khuri and colleagues [244] also demonstrated that a high percentage of postoperative complications and deaths occur after 30-days postoperatively. Using NSQIP data from 105,951 patients who underwent 8 types of operations performed between 1991 and 1999, the overall 30-day mortality rate in the total study population was calculated at 3.07%. However,
excess surgical mortality could occur up to 180 days postoperatively depending on the nature of the procedure. Questions about the magnitude and duration of perioperative mortality are an active area of research for Dr Doug Campbell and colleagues in DAPM at Auckland City Hospital.

6.6 Conclusion

This chapter has presented the findings from the third PAR cycle. Research in this cycle sought to address the third objective of this thesis: to describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. This research allowed us to make an assessment as to the value of this information for use in preoperative risk assessment and communication. Analysis of data gathered directly from the patient care environment was demonstrated to provide valuable insights into perioperative mortality that are relevant to anaesthetists’ own clinical settings. Although this information must be interpreted with a degree of caution, it may be used in shared surgical decision-making and the planning of perioperative patient care. The findings from the three cycles PAR presented in Chapters 4–6 are drawn together in the following concluding chapter.
Chapter 7: Conclusions

7.1 Introduction

Each year millions of patients worldwide undergo elective surgery to correct a non-life-threatening health condition. For most patients, the risks of surgery and anaesthesia are low, but complications after surgery are an important cause of death. There are limited data on the risks of dying that are relevant to the anaesthetist’s own clinical setting, so the risks of surgery can be poorly estimated and communicated. To improve the situation, the research reported in this thesis sought to provide actionable insights into perioperative outcomes for patients coming forward for elective surgery. It is hoped that these findings will assist anaesthetists to have meaningful conversations with their patients as part of the process of shared surgical decision-making during the preoperative assessment.

In this chapter, I present the concluding remarks about all three of the PAR cycles described in Chapters 4–6. First, I reflect on the research problem and the three objectives of the research. Second, the findings from each PAR cycle are considered and related back to the objectives and the overall research problem. Third, the contribution of the thesis to the wider discourse and the theoretical, practical and educational implications of the research are stated. Fourth, I outline the limitations and scope for future research. Finally, the chapter, and this research journey, are brought to a close with some final remarks.

7.2 Reflecting on the research problem and objectives

This study originated from a series of informal conversations between Dr Campbell and myself that occurred throughout the normal course of our everyday work in DAPM at Auckland City Hospital as a specialist anaesthetist and clinical research analyst, respectively. Building on our existing knowledge of HISs and hospital processes for delivery of perioperative care, we articulated the research problem for this thesis:

The current business intelligence capability in preoperative care does not provide anaesthetists with sufficient, actionable insights relevant to their own clinical settings in support of risk-benefit assessment before elective surgery.

To address this problem, we initiated a project to develop a BI prototype for use in preoperative care. The aim of the project was twofold: (1) to gain actionable insights into perioperative outcomes for patients undergoing elective surgery in the care system that generated the data and (2) to make these insights available to anaesthetists at the point of care to support risk-benefit assessment and communication for shared surgical decision-making during the preoperative assessment. In keeping with the interdisciplinary nature of medical
informatics, the objectives of the research sought value for both anaesthetists and IT practitioners working in the BI space.

The objectives of the research were:

1. To investigate the appropriateness of an ISD methodology, namely Multiview2, to inform the development of a BI prototype in the healthcare sector. There is a paucity of evidence to guide BI development so a web development methodology was chosen to expand the body of literature in this space. The features of Multiview2, specifically its support for development that is contingent, even-handed and situated see the approach well suited to early development efforts such prototypes in healthcare.

2. To explore how the work of risk assessment and communication during the preoperative anaesthetic assessment is achieved.

3. To describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. This objective allowed us to make an assessment as to the value of this information for use in preoperative risk assessment and communication.

With these objectives in mind, the research proceeded in keeping with the pragmatic and interpretive epistemologies. Three PAR cycles were conducted during 2011–2013 (Figure 45).
In Chapter 4, the findings from the first PAR cycle were presented. Research in this cycle sought to address the first objective of this thesis: to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI in the healthcare sector. The indicative and stereotypical methods of Multiview2 were contrasted with what actually occurred in practice for three of the four quadrants in the methods matrix – organisational analysis, information modelling, and software development. The study identified three stereotypical roles in BI development, namely orientating, discovering, and presenting. Three outcomes of BI development were also discovered: a plan of action as a result of organisational analysis; S2T map and physical data models of source systems, and dimensional models of the target system from data modelling activities; and a BI artefact from technical development. This exercise led to the first revision of the Multiview2 framework for BI development.
Following on from this, the findings from the second PAR cycle were presented in Chapter 5. Research in this cycle sought to address the first and second objectives of this thesis. The first objective, mentioned previously, was to investigate the appropriateness of the Multiview2 methodology to inform the development of a BI prototype in the healthcare sector. The second objective was to explore the work of risk communication at AAC. The research was presented using the fourth and final quadrant of the methods matrix – sociotechnical analysis. Qualitative interviews with specialist anaesthetists were conducted to gain an appreciation of how anaesthetists conduct the work of risk communication in actuality. Analysis of these data showed that the interactional and circumstantial influences on anaesthetists’ communications with patients, as part of the shared decision-making that occurs prior to surgery, are varied and complex. The indicative and stereotypical methods of the Multiview2 sociotechnical analysis were contrasted with the use of qualitative interviews in this PAR cycle. This exercise led to the second and final revision of the Multiview2 framework which is thought to be appropriate for BI development. The revised framework is shown in Figure 46.

The findings from the third and final PAR cycle were presented in Chapter 6. Research in this cycle sought to address the third objective of this thesis: to describe 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012. A single-centre, retrospective cohort study was performed using RCD from three HISs to assess the value of the information in the prototype for the purpose of risk assessment and communication. Analysis of data gathered directly from the patient care environment was shown to provide valuable insights into perioperative mortality, even if these insights are comparable to international literature. Although information derived from RCD must be interpreted with a degree of caution, it may be used in shared surgical decision-making and the planning of perioperative patient care. The data generated by the three PAR cycles distilled several findings, which have led to new conclusions about BI in preoperative care. These learnings are discussed in the following section.
Figure 46. The Multiview2 approach to systems development [534] (top) compared with the revised Multiview2 framework for BI development (bottom).

7.3 Drawing the findings and conclusions together

Accurate and timely information about perioperative outcomes that is relevant to the anaesthetist’s clinical setting represents an important contribution to shared decision-making
before surgery. Owing to advances in surgical and anaesthetic techniques and the changing demographic of the surgical population, higher-risk surgery is now being performed on higher-risk patients [29] so an approach to perioperative care that is predictive, preventative, personalised and participatory [763] is increasingly required. The current trend towards individualisation of treatment means that the patient may wish to know what the risks are for him or her as an individual [29]. Indeed, well-informed patients may choose to forgo surgery or opt for less invasive management after being informed of the risks [47, 48]. Whereas conventional methods, such as RCTs, are designed to assess the average treatment effect in the group of patients under study, patient-centred research strategies grounded in RCD may permit a more individualised approach to risk assessment and shared surgical decision-making, simply because vast amounts of data are collected about the patient and their routine care, in ignorance of any specific outcome.

It follows that the place of BI in preoperative care is without doubt an important one. BI is concerned with the processes that generate data, the technologies that transform it and the unique circumstantial and interactional influences that make up the context in which data will be sourced and decisions will be made. It is inherently responsive to clinicians’ and patients’ decision-making requirements, providing avenues for exploration and preliminary testing of hypotheses. BI technologies permit the automation of data processing to deliver information that is easily accessed and is current as at the last extract, transform, load (ETL) run rather than the publication date. Anaesthetists described time pressures at AAC, which meant that issues of risk communication were not always given the time that they deserve. By providing a consistent, concise representation of information about perioperative mortality that was easily accessible at the point of care, it is hoped that the BI prototype goes some way towards ensuring that anaesthetists have the “right” information at their fingertips. Yet, what appears to be the most important point of all is that BI is situated. Decision-making in the preoperative period is not likely to be based wholly on fact. Even if mortality rates are comparable with international literature, there is something authentic and meaningful about risk information, which is derived from care that was delivered within the same walls, by one’s colleagues, to a great many past patients.

This study has also highlighted the requirement for strong clinician-IT operational alignment [672] because BI is not agnostic of domain. Secondary utilisation of healthcare data has received much attention and the application of both quantitative and qualitative methods to solve problems and predict outcomes using big data has become increasingly commonplace. Yet, one of the salient revelations of the big data age is that domain knowledge and BI
development cannot be separated [764]. BI requires learning on both sides of a great many computer screens. From the theatre nurses and anaesthetists who record pre-, intra- and postoperative care to the theatre coordinator who allocates surgeries to operating rooms, and from the application support analyst who presides over the business rules that govern the entry of data to the database administrator who situates and maintains the application database, there are a great many people and processes that bear influence on the BI developer’s work. It is widely acknowledged that successful sociotechnical design of IS in healthcare begins with a detailed understanding of the systems and practices in which they are intended to function [626, 765]. Successful BI development, then, requires an understanding of those practices on both sides of the information system – both of the individuals responsible for entering or amending source data and the individuals wishing to use it.

A corollary to this point is that BI developers must come to understand the nature of healthcare work. However, we cannot do this from the vantage point behind the computer screen. As BI developers, we are trained to think logically, to determine how to move from one stage table or line of code to the next. But, this is an all too common representation of the developer. We are also trained to be creative and abstract thinkers. We think about how to architect our solutions, how to dimensionally represent business processes in a data warehouse and how to position charts and tables for readability on a report. Anaesthetists and patients construct interpretations in their interactions, and so do we. In thinking beyond the next line of code and seeing their work as interpretive, interactive and iterative, developers are able to move beyond the solution in front of them and instead see the social system and the technology as mutually exclusive components of something bigger. This is at the heart of the revisions of Multiview2 for BI development in this research. Only then may we address the narrow, structured and misguided rationalisation of medical work that is prevalent throughout much of healthcare and the failures of HISs that result from it.

7.4 Research limitations

Each and every study is subject to limitations. It is important to acknowledge these limitations to enable the reader to assess the quality and generalisability of the research. Although PAR is an effective method for gaining firsthand knowledge of practice, one of its oft-cited shortcomings is that the researcher is not impartial and can become too involved in the “doing” to the detriment of the “research” [79, 605]. However, the blurring of the roles of researcher and researched also creates opportunity for introspection and self-reflection, and lends credibility, situatedness and depth to the research process [766]. Whereas alternative research approaches define the respective roles of researcher and researched as the creator and
source of knowledge [766], PAR subscribes to the notion that experience is the foundation for knowing [767]. Through collective enquiry, self-reflection and continuous experiential learning, this study gave rise to legitimate knowledge forms that improved local practice. PAR permitted Dr Campbell and myself to exercise our knowledge of informatics, and anaesthesia in a way that accommodated the unique problem situation and therefore contributed to a more developed framework and in-depth understanding of BI in preoperative care.

The context-dependency inherent in PAR typically leads to difficulty generalising the findings from studies that use the method [79]. This research is about the development of BI technologies to provide actionable insights to anaesthetists in support of risk-benefit assessment and shared decision-making before elective surgery. We discovered four stereotypical roles and outcomes of BI development in healthcare; complex interactional and circumstantial influences that come to bear on an anaesthetist’s communication about anaesthesia and surgery; an understanding of 30-day and 1-year perioperative mortality, and generally, a great appreciation for the work of BI in the space under study. Importantly, the complexities of healthcare work are not specific to anaesthesia and surgery; Strauss [712] and Berg’s [714] works are a testament to this. Similarly, the practice of BI gives emphasis to “modelling for process” rather than for specific reports and therefore many of the tools and techniques for development are also likely to be applicable to other healthcare contexts. Although the domain within the healthcare setting may change, the requirement to learn from both sides of multiple computer screens does not. The learnings from this study can be transferred to other, similar situations, but may not generalised for all forms of BI development outside of the healthcare setting.

Despite these limitations, this thesis has demonstrated a thorough application of the PAR method. The research was conducted over a period of two years so we were able to track and interpret the consequences of our actions over a significant length of time. Continuous cycles of action and reflection throughout this period provided change-based data and sense-making. Dr Campbell and I both participated in the research process as we went about organising the PAR effort. Throughout the study, we shared in the decisions about the direction of the process and participated in core activities. Participation provided us with a level of control that gave the research a contextual focus, which is at the heart of PAR. Finally, data were collected, interpreted and the resulting knowledge diffused in email communication, corridor conversations, institutional presentations and now via this thesis. This thesis fulfils the ideal
of making dual contributions to scientific knowledge and practical problem solving by way of research that exhibited both purpose and value choice.

7.5 Contribution and implications

Despite the limitations described above, this research has made significant contributions to the body of knowledge. Contribution to dialogue in the domain, by way of informal feedback and disseminating findings, is an important means of guiding the research process and increasing the research contribution to both theory and practice. Whilst the findings from this study have not yet been formally disseminated in the form of conference proceedings or journal articles, they have been presented locally, at the regular departmental Clinical Forum Meeting in late 2011, again at the Annual Anaesthetists Research Meeting in August 2012, and in the form of a poster for the Auckland DHB celebration week in November 2013. Alongside informal conversations by way of email and “corridor conversations”, these presentations generated feedback in the form of suggestions for improvement, requests for change, questions seeking clarification and general interest which shaped the research and ultimately the ISD.

7.5.1 Implications for research

The revision of Multiview2 for BI development in line with Vidgen’s [533] approach has grown the body of knowledge in the area of BI development. This thesis has shown that Multiview2 can be used effectively and productively for BI development in the healthcare sector. The revised framework adds to the body of knowledge by presenting four quadrants – organisational analysis, data modelling, technical development and sociotechnical analysis – each annotated to highlight the different emphases that are observed throughout a BI project as the developers move between the social and technical sides of the methods matrix. Organisational analysis is stereotyped as orientating, data modelling as discovering, technical development as presenting, and sociotechnical analysis as perceiving and interpreting. The methods matrix is updated to show the outcomes of the quadrants: a plan of action as a result of organisational analysis; S2T map, physical data models of the source systems and dimensional models of the target from data modelling; a BI artefact from technical development; and appreciation of work practices from sociotechnical analysis. A successful BI development project is likely to need a mix of all of these aspects, though in what quantities and at what times remains to be seen, reflecting the contingent nature of the local methodology.

For the PAR contribution to be valid and useful, the research process must result in desirable change. This thesis has brought about desirable change by instigating additional research
endeavours in precision medicine. Following on from our work, Dr Campbell pursued a research grant for the Precision Driven Health research programme to study epidemiology and estimation of long-term surgical mortality using mathematical models. He is the clinician-lead for the two-year, Auckland-based project, which aims to describe the risk of postoperative mortality for individual patients with greater precision than is permitted by existing surgical risk calculations [768]. The $37.8 million programme is currently NZ’s largest ICT research project, involving healthcare software development company Orion Health, the University of Auckland and three large DHBs across NZ. Dr Campbell’s interest in the area of big data, BI and medical informatics has, for the most part, developed out of the work undertaken for this thesis.

7.5.2 Implications for practice
The implications for practice of this research pertain to both IT professionals and anaesthetists. This thesis has shown the importance of social as well as the technical aspects of BI development. From source system discovery, data profiling and data modelling to technical development and planning, requirements gathering and sociotechnical analysis, the work required is vast. Common to all of these activities, and perhaps made clear by the symmetrical treatment of social and technical aspects of ISD, is the need for “talk work”. Not in the sense that talk work is scheduled into a software development sprint or added to a Post-it note on a Kanban board, but in the sense that it is an item in the “Doing” swimlane of the active sprint that is never quite ready to be moved to “Done”. Talk work is needed to disentangle the relation between the data on the one hand and the people and processes that created or shaped it on the other. Talk work is also necessary to broaden the developer’s awareness of the complexities of medical work that make up the context in which the artefact will be deployed. Yet, talk work is not confined only to the social aspects of BI development, for there are architecture choices to be made and lines of code to review. What is clear, however, is that talk work underpins frontline and back-room learning on both sides of a great many computer screens.

This thesis also has implications for surgical shared decision-making when perioperative complications are of concern. We have shown that it is possible to gain actionable insights into perioperative mortality for patients undergoing elective surgery in the care system that generated the data, and also that it is possible to make this information available to anaesthetists to support risk-benefit assessment and communication during the pre-anaesthetic assessment. In doing so, anaesthetists are able to have meaningful conversations with patients and to assist them to make the choices that best meet their needs through early discussion of
harm, benefits and expectations, with the aid of information about perioperative mortality that is relevant to their own clinical setting. This is important because well-informed patients may choose to forgo surgery or opt for less invasive management after being informed of the risks. As the surgical patient population ages and the burden of comorbid disease grows, information about the risks of undergoing surgery will be increasingly important to avoid unnecessarily invasive or futile procedures. Choice, chance and communication lie at the heart of preoperative patient-centred care, and therefore the value of accurate, timely and relevant information about perioperative outcomes should not be underestimated.

7.5.3 Implications for education

The study has implications for tertiary education in both information and medical sciences. Undergraduate teaching in computer science and information systems seeks to “teach the tool” – UML modelling for systems analysis and design or programming languages such as C# or Java for application development – but is without strategies to help students to “learn the business”. The craft of ethnography or even the qualitative interview is not commonly taught until postgraduate level, and even then these methods are taught in the context of research not practice. Still, these techniques are not commonly employed in the ISD and they must be taught to ensure that they are used effectively. If we are to dispense with the artificial separations between the social and the technical and to truly value work in the sociotechnical quadrant of Multiview2, then surely our undergraduate teachings in the information sciences should incorporate some training in these techniques. The implications for medical informatics education are equally important. The literature is replete with calls for education and training of “special people” who are capable of bridging or spanning the clinical and application domains [10, 11]. Education in medical informatics provides a conceptual basis for understanding the worldview of the other, and in doing so, permits greater awareness of the social and technical aspects of ISD, both of which are required for successful development and implementation of HISs.

The study also has implications for education of anaesthesia trainees and specialist anaesthetists. There are a great number of uncertainties and challenges involved in the discussion of risk with colleagues and patients alike. An increased focus on communication skills training for anaesthetists, especially with respect to risk communication, is needed to help patients to make the choices that best meet their needs. During their interviews, a small number of anaesthetists recommended the development of a training module in the Australian and New Zealand College of Anaesthetists’ curriculum on informed consent and risk communication for trainee anaesthetists. Others suggested professional development for
anaesthetists through role-playing of consent discussions could raise awareness of the importance of topic. These considerations have also been raised elsewhere in the literature [41], signalling that the need for these developments extends beyond the immediate institution.

7.5.4 Directions for future research

The directions for future research are broad as they are deep, but two immediately stand out. First, further research is needed to understand the nature of clinical and IS work in perioperative care. A deep, rich and nuanced understanding of healthcare is necessary to address the twin issues of adoption and failure of IT/IS in healthcare. Although healthcare is unique in many respects, the “no one understands health care fallacy” [769] implies that it is not possible for anyone outside of the domain to understand it. This has profound implications for knowledge management within the healthcare sector. To dispel this fallacy, Karsh and colleagues suggest that clinicians should be “studied” with the aim of broadening the developer’s awareness of the complexities of medical work. Understanding these complexities is not simply a matter of asking clinicians what they want, and therefore further qualitative research is needed to understand their work in perioperative care. Anaesthetists are set to continue their migration outside of the operating room and towards the start of the pathway for elective surgery [47]. With a focus on transforming RCD into local insights, BI is set to become increasingly valuable in anaesthetists’ pursuit of early shared surgical decision-making and, improved perioperative outcomes for all [770]. The results of observations, interviews and especially future experiences with the revised Multiview2 framework for BI development in other healthcare settings and applications will increasingly be needed to optimise ISD.

Further research is also needed to access, transform and present other local outcome data. Death at 30 days or in the long term is not likely to be the sole determinant for most patients when choosing whether to undergo surgery [29]. Reflecting on one anaesthetist’s observation of “a fate worse than death”, information on postoperative function and quality of life are likely to be equally important to clinicians and patients alike. However, there are limited local data for these outcomes, in part due to issues with data capture and interpretation. Equally, there are limited data on outcomes for patients who choose not to undergo surgery. HISs should implement structures for data capture that derive from intimate, firsthand knowledge of the ongoing processes of care [691, 692] if we are to successfully facilitate translation between primary and secondary use of healthcare data for these outcomes. Research into the design of these systems is needed. Finally, research is needed to refine methods for data
processing and analysis to ensure that these too remain true to the premise of disentangling rather than severing data from the context of its production.

### 7.6 Concluding remarks

This chapter has presented the conclusions of this thesis. The purpose of the research reported in this thesis was to gain actionable insights into perioperative outcomes for patients undergoing elective surgery in the care system that generated the data. Additionally, this research sought to make these insights available to anaesthetists at AAC to support risk-benefit assessment and shared decision-making before elective surgery. Over the course of three PAR cycles, the objectives of this thesis were investigated. In Chapters 4 and 5, the stereotypical roles and outcomes for BI development were elicited and this resulted in the revised Multiview2 framework that is considered appropriate for BI development in the healthcare sector. Also in Chapter 5, we saw how the interactional and circumstantial influences on anaesthetists’ communications with patients, as part of the shared decision-making that occurs prior to surgery, are varied and complex. Finally, in Chapter 6, we saw that 30-day and 1-year perioperative mortality rates for adult patients who underwent non-cardiac surgery at Auckland City Hospital from 2002 to 2012 were comparable to those published internationally, but still held value for Auckland City Hospital anaesthetists by virtue of their timeliness, relevance and quantity. Throughout these research cycles and through the building of the BI prototype, this thesis has shown that it is not only possible, but valuable, to seek out actionable insights into perioperative outcomes from RCD. Choice, chance and communication lie at the heart of patient-centred preoperative care. With ever-increasing numbers of elderly and infirm patients contemplating surgery, we, both clinicians and IT professionals, all have much work to do.
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