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**Human error and latent risk in incidents  
in anaesthesia in New Zealand**

A thesis  
submitted in partial fulfilment  
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of  
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by  
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## **Abstract**

Research has shown that human error in anaesthesia is a major contributor to critical incident in anaesthesia, what is unclear is how this occurs and what impact these incidents have on patients. The purpose of this thesis was to examine human error in anaesthesia using Reason's (1990) framework of error and Swiss Cheese Model to identify the stages of anaesthesia in which errors occur, the frequency and severity of those errors, and the role of fatigue, stress, and usability in human error in anaesthesia. A two stage process was used to collect information on human error in critical incident. The first stage consisted of a task analysis and Flanagan's (1954) critical incident analysis which allowed for the collection of information on the anaesthetic process, this information led to suggestions for a questionnaire to be used to collect data which could be quantitatively analyzed. In the second stage, a questionnaire was constructed and taken online by participants sent invitations from their respective District Health Board in New Zealand. A small sample size of data was acquired (n=12 responses) of which 8 were complete and used. Results were analyzed by a critical incident analysis. Human error was found to occur during all stages of anaesthesia with induction representing the most incidents and emergence the least. Incidents involving human error were found to be rare, occurring between once per yearly quarter to a few times per lifetime. Most incidents were found to be near misses, and almost a quarter of incidents were found to be of harm, of these only one was judged to be of moderate harm. Fatigue and stress were found to be associated with half of incidents, and equipment design was found to only be associated with a few incidents. This investigation is effective in highlighting

examples of modern critical incidents of anaesthesia. These results indicate that fatigue and stress possibly play large roles in contributing to human error in anaesthesia and may be good areas for future research.

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## Chapter 1: Introduction

The patient safety movement which many attribute to the publication of *To Err is Human* (Kohn, Corrigan & Donaldson, 1999) was one of the first quality improvement movements to gain wide public support in addition to being amongst one of the largest reports demonstrating that human errors account for a large amount of preventable injuries and deaths. Kohn Corrigan and Donaldson (1999) found that if the rate of human error from 1982-1997 were extrapolated to all hospitals in the USA human error would be associated with 44,000-98,000 deaths per year. This figure they claim is higher than deaths attributable to motor vehicle accidents, breast cancer or AIDS (Kohn, Corrigan & Donaldson, 1999, p. 26).

The implications of human error in healthcare are obvious! That is, there is a relationship between human error and mortality and morbidity, however there are some less obvious reasons for this which Merry and Smith (2001) have summarized well. Merry and Smith (2001) suggest reducing human error is important because “errors tend to reduce the chances of achieving a given outcome or the margin of safety associated with a particular activity” (Merry & Smith, 2001, p. 73). The study of human error in healthcare has revolved largely around pharmacy and medication prescribing human error, therefore specialties such as anaesthesia are largely underrepresented, and questions regarding current safety issues in this regard remain largely unanswered. This thesis will begin with a literature review which will examine Reason’s (1990) Framework of Error and Swiss Cheese Model (SCM), the frameworks of human error in anaesthesia, research on the different types of human

error in anaesthesia, the mortality and financial consequences of human error in anaesthesia, and research on fatigue, stress, and equipment design factors which contribute to incident in anaesthesia.

### **Anaesthetic error**

Human error has been described in literature in various ways in terms of models and frameworks describing the meaning and classification of error, and the way in which errors contribute to accidents or catastrophes (Dekker, 2006; Reason, 1990; Reason, Hollnagel & Paries, 2006). These frameworks are important as they help researchers simplify the process of understanding the relationships between causal factors and human error, this ideally enables development of strategies for reducing human error (Simpson, Horberry & Joy, 2009). Reason's (1990) Taxonomy of Error and Swiss Cheese Model has been suggested to be one of the most widely accepted frameworks of human error (Dekker, 2006; Reason et al., 2006). These frameworks serve to clarify what error is caused by, how errors occur, and how errors relate to incidents.

Reason (1990) defined human error as the failure of a planned action or the use of an incorrect plan to achieve an aim. Reason categorized human error as instances of slips, lapses, and mistakes, each of these represent different errors in cognitive processing. Slips describe instances in which actions fail to happen according to an intended plan, these are often due to a failure in the processes directing individuals' actions such as in failures of perception, attention or psychomotor skills (Reason, 1990). Attention failures have been suggested to explain many slips, these types of

failures occur because inadequate amounts of attention are allocated to tasks, this is not surprising given that attention is a limited resource that can be exhausted as a result of both internal and external events competing for control (Reason, 1990).

Mistakes involve the formation of incorrect intentions or plans that individuals mentally use to complete tasks. Mistakes have been identified as more difficult to recognize, often being corrected only as a consequence of intervention of some external agent (Reason, 1990). Mistakes consist of two forms, rule-based mistakes and knowledge-based mistakes. Rule-based mistakes occur when a bad rule is applied or a good rule is misapplied these rules may originate from the individual or protocols from external bodies (Wheeler & Wheeler, 2005). As an example, Wheeler and Wheeler (2005) cite a real life example of an anaesthetist who used a nasotracheal tube orally on a patient. This tube become kinked, this was not recognized and led to the death of the patient. The error was breaking the rule of using a tube intended for other purposes. Knowledge-based mistakes occur as a consequence of rule-based reasoning being exhausted and individuals using their knowledge to solve problems. This type of mistake is special in that it reflects either a person's lack of awareness of rules (such as trainees who might be just learning the rules) or novel situations which in which it is difficult to apply a rule to. According to Reason (1990), it is when knowledge has to be used that errors are more likely to occur (Wheeler & Wheeler, 2005).

Lapses are failures in the processes of retrieving or remembering information using short and long term memory (Reason, 1990). Because lapses are failures in

memory they are usually only obvious to the person who experiences them, therefore they are usually the least observable type of error (Wheeler & Wheeler, 2005). Lapses are similar to slips in that these errors do not occur as a result of intentionality, this is why slips and lapses are often referred to as errors of absent-mindedness (Reason, 2013).

Violations refer to instances of intentional planning which conflict with prescribed procedures or rules (Reason, 1990). Violations have been suggested to increase the chance of error as well as reducing safety (Merry & Smith, 2001). Violations have been suggested to occur due to deviations from planned procedure being perceived as offering some sort of favourable trade-off, such as by a reduced amount of effort required, time spent, and etc. According to Merry and Smith (2001), the perceptions and risk analysis that lead to violations are erroneous within anaesthesia because safety is incorporated into the rules within anaesthesia and therefore violations always increase the chance for harm. Violations have been suggested to be due to a variety of factors such as: established norms (routine violation), high costs for compliance (situational violations), novel situations in which rule breaking is perceived to be unavoidable or rule following to be ineffective (exceptional violation), and individuals attempting to increase stimulation (optimising violations) (Simpson et al., 2009).

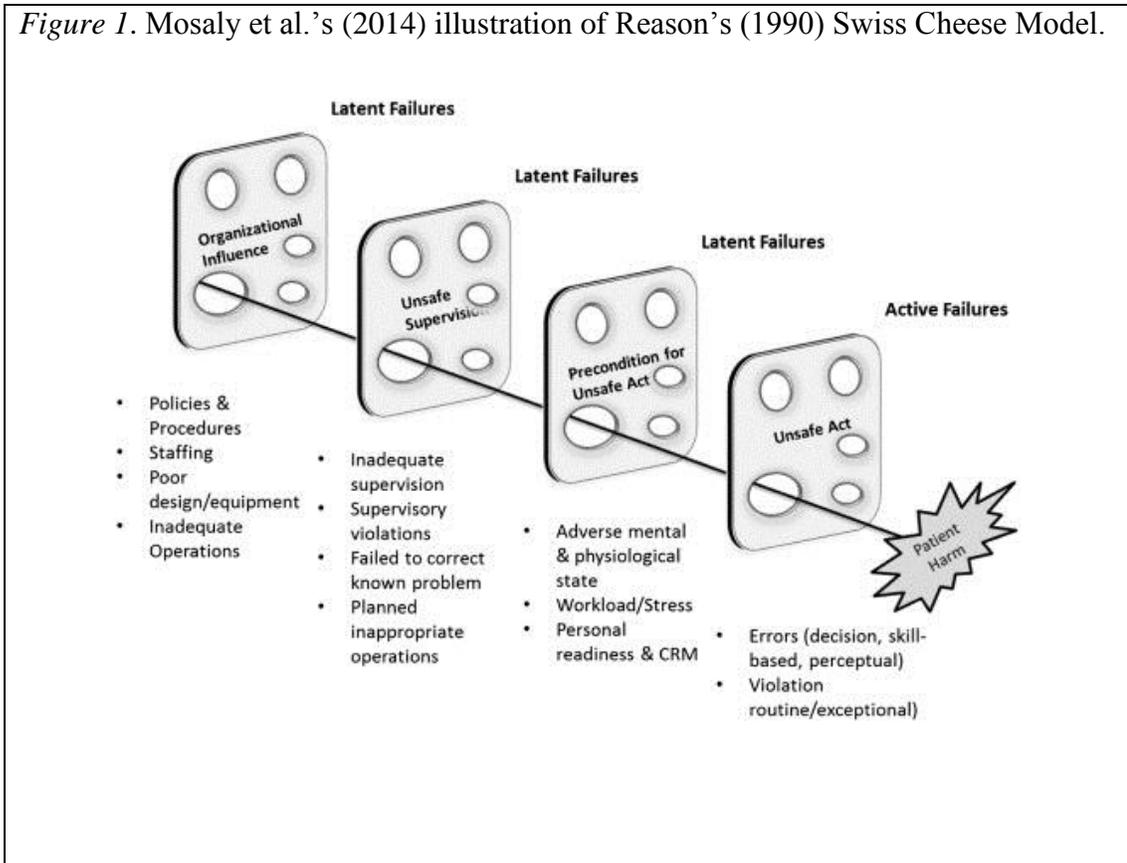
### **The Swiss Cheese Model.**

Understanding human error requires not just a taxonomy of error but also a model of how errors occur and relate to one another; this has been a large part of

human factors research and literature (Stanton, Hedge, Brookhuis, Salas & Hendrick, 2004; Stanton, Salmon & Walker, 2003). Reason's (1990) Swiss Cheese Model (SCM) provides a framework for helping researchers better understand how error and incidents arise in complex systems. The SCM proposes that the observable acts of human error (active failures) are influenced by characteristics of the organization, management and personnel, characteristics of these that contribute or do not prevent error are considered latent failures (Reason et al., 2006). The SCM endorses what Dekker (2006) termed the new view of human error, this means there is an understanding that the SCM recognizes that human error is a symptom or outcome rather than the primary cause of an incident and that there is an understanding that complexity can contribute to creating incidents.

The SCM has been suggested by Simpson et al. (2009) to be analogous to the model of disease and treatment wherein diseases, which are latent and similar to latent failures, cause observable symptoms which are similar to active failures. Similarity exists as the SCM and medicine suggest that focusing on treating symptoms at times may be an appropriate solution, but it may sometimes not be the optimal long term solution. The optimal long term solution is more often to identify the cause and to attempt a cure, in the SCM this means that unless active failures are investigated at a latent failure level, active failures will simply continue to occur and possibly worsen in the future. While there are criticisms of the SCM, such as it being non-specific and possibly placing too much emphasis on latent conditions rather than active failures (Reason et al., 2006), most of the criticism regard problems applying it

more so than the central ideas of the model, that is, no one has suggested it should not be used.



The SCM derives its name from the commonly used representations of the model (see Figure 1) which depict latent failures within levels, with each level being represented by a slice of cheese. These levels within the layers of security are described as organizational influences, unsafe supervision practices, and preconditions for unsafe acts. Within each of these layers of security there are latent failures which are depicted as holes, when latent failures exist within different layers of security, there is a greater potential for accidents to occur, these systems would bear close resemblance

to a block of Swiss cheese. Within anaesthesia there is literature which describes these latent failures, this literature is discussed next.

### **Latent risks in anaesthesia.**

#### ***Human error from organizational influences.***

Two organisational factors have been identified as latent risk factors in anaesthesia: staffing levels and the presence, and adherence, of procedures (Beuzekom, Boer, Akerboom & Hudson, 2010). Understaffing according to Beuzekom et al. (2010) is problematic as it increases workload and time pressures, which could increase unsafe actions such as risk taking and violations. Understaffing is also problematic because it can lead to workloads which may increase fatigue in workers, as well as making it difficult to ensure that there is adequate supervision of staff.

Procedures have been suggested to be ignored due to violations occurring on a routine basis, anaesthetists personal beliefs regarding the importance of a violation, the lack of a clear protocol existing for specific situations, and resistance to a procedure or protocol (Beatty & Beatty, 2004; Beuzekom et al., 2010). Anaesthetists personal beliefs regarding the importance of violations have been found to influence violations in which there was a failure to visit patients before surgery, to perform pre-anaesthesia equipment checks, and to silencing of alarms during operation (Beatty & Beatty, 2004). Violations of procedures have been found to be one of the most frequent contributing factor to incident in some anaesthesia research (Dhillon, 2003).

### ***Human error from supervisory failures.***

Supervisory failures describe latent failures that occur within the chain of command. Supervisor failures consist of inadequate supervision, planned inappropriate operations, failure to correct problems, and supervisory violations (Reason, 1990). Inadequate supervision in anaesthesia has been found to contribute to medical errors and violations amongst trainees (Oliveira, Rahmani, Fitzgerald, Chang & McCarthy, 2013). Inadequate supervision has been cited for a high amount of pregnancy related deaths in anaesthesia (62.5%) and other instances of mortality (Gannon, 1991; Mhyre, Riesner, Polley & Naughton, 2007). Inadequate supervision has been shown to be decreased recently in anaesthesia. Currently conflicting demands on supervisors and accessibility to direct supervising of trainees are some of the greatest barriers to improvement (McHugh & Thoms, 2005; Underwood & McIndoe, 2005).

### ***Human error from preconditions for unsafe acts.***

Preconditions for unsafe acts describe latent failures in which an operation or event is not adequately prepared for, this involves either substandard conditions of the operators, the environment and the practices used by operators (Reason, 1990). Fatigue and stress are two variables which can adversely impact upon the mental state of operators, in anaesthesia these factors have been found to be associated with incidents involving human error (Arnstein, 1997; Buckley, Short, Rowbottom & Oh, 1997; Cooper, Newbower & Kitz, 1984; Dhillon, 2003). These have been suggested to occur in anaesthesia due to a variety of factors such as work practices and critical

and unprepared situations, currently safe hours of work standards and stress inoculation training have been suggested to reduce fatigue and stress (Petrosoniak & Hicks, 2013; Tewari, Soliz, Billota, Garg & Singh, 2011).

Equipment design failures describes a variety of latent failures within the technology used by individuals in a setting (Reason, 1990). These have been described as confusing designs in research such as in controls which are difficult to discriminate from others (Arnstein, 1997; Weinger, 1999). Equipment design in research has been shown to be associated with incident with several different types of equipment such as breathing circuit equipment and anaesthesia machines (Craig & Wilson, 1981; Weinger, 1999).

The practices of operators describe the coordination and the processes of coordination between individuals and groups (Reason, 1990). Communication and teamwork, two requirements for coordination, have been suggested to be sources of latent failures in recent research (Kothari, Gupta, Sharma & Kothari, 2010; Beuzekom et al., 2010). Communication has been suggested to be the third most common factor associated with incident in Kothari et al. (2010), and has been found to contribute to a small amount of violations (0.8%) in other research (Lingard et al., 2004). Teamwork has been found to contribute to 22-32% of incidents in some research and has been cited as contributing to incident more than from anaesthetist's general lack of clinical skills (Manser, 2009). Teamwork, according to Gaba (2010) has received barely any evaluation, therefore future research is needed to identify how latent failures in it can be reduced.

## **Classifications of human error in anaesthesia**

Classification of human error in medical systems have differed over time due to researchers' scope of human error varying between studies. Waluube (2011) has described the major classifications of human error in medical systems as three frameworks originating from Gruver and Frie's (1957), Leape et al.'s (1991) and Cooper et al.'s (1984). Below these classifications are discussed and later a framework for interpreting rates of incident is discussed.

Gruver and Fries (1957) classification consists of a concept termed diagnostic errors which they define as "errors which occur due to a lack of necessary experience, errors of omission, misleading test results, and errors due to problems with physical examination "(Waluube, 2011, p. 35). Diagnostic errors help identify primarily mistakes and the active failures associated with them. This classification has been used within a variety of studies to identify errors in adverse events, malpractice claims, and other studies (Henriksen et al., 2005). Diagnostic errors have been found to explain a high amount of adverse events (0.6-78.6%) and a moderate amount of error in malpractice claims (3-23%) (Schiff et al., 2007).

Leape et al.'s (1991) classification of medical error consists of five types of error, they are: performance based, diagnostic based, drug treatment, system based, and prevention based. Leape et al.'s classification helps identify a variety of slips, lapses, and mistakes and their relation to active and possibly latent failures. Unfortunately no other study could be found which had used this classification. The categories of this classification can be seen in Table 1.

Table 1.

*Leape et al. 's (1991) classification of medical error.*

Type of Error	Definition
Performance error	Errors in which there is inadequate preparation of patients before procedure, technical errors, inadequate monitoring of patients after procedure, use of inappropriate or outmoded forms of therapy, avoidable delays in treatment, and where the doctor or other professional practice outside their area of expertise.
Diagnostic errors	Errors in which there is a failure to use indicated tests, failure to act on results or findings, the use of outmoded or inappropriate diagnostic tests, avoidable delays in diagnosis, and physician or other professional practicing outside their area of expertise.
Drug treatment errors	Errors in which the incorrect dosage or method of use occurs , where there is inadequate follow-up of therapy, use of inappropriate drugs, avoidable delays in treatment, and the primary physician or other personnel practicing outside area of expertise.
System-based errors	Errors in which there is defective equipment or supplies, inadequate or a total lack of equipment or supplies, an inadequate monitoring system, inadequate reporting or communications, inadequate training or supervision of physician or other personnel, delays in provision or scheduling of services, inadequate staffing, and inadequate functioning of hospital services.
Prevention-based errors	Errors which include failure to take precautions to prevent accidental injury, failure to use indicated tests, failure to act on results of tests or findings, use of inappropriate or outmoded diagnostic tests, avoidable delay in treatment and physicians or other personnel practicing outside their area of expertise.

Cooper et al.'s (1984) classification of medical error consists of four types of error concerning actions occurring regardless of intention (technical errors); as a result of a lack of experience, incorrect planning, or intentions (judgmental errors); attention failures (monitoring or vigilance failures); and other reasons (either unclassifiable or not-human error). Cooper et al.'s classification helps researchers identify error and differs the most from other classifications by focusing on error at a

conceptual level with concepts very similar to Reason’s (1990) concepts of human error. To date Cooper et al.’s classification has been used in a small amount of research which has found technical skill and judgement to explain most error in anaesthesia (Cooper et al., 1984; Manghnani, Shinde & Chaudhari, 2004).

Table 2

*Cooper et al.’s (1984) classification of error*

Category	Definition
Technical error	“[Technical errors are those] in which the action taken is not the action intended, arise from deficiencies of technical skill or from poor human-factors design in the equipment or apparatus involved.”
Judgmental errors	“[Judgmental errors are those] in which the action represents a bad decision, arise from lapses in training or poorly developed decision making skills.”
Monitoring and vigilance failures	“[Monitoring and vigilance failures] are those in which the essence is a failure to recognize or act upon visible data requiring a response.”

All the classifications mentioned prior have various limitations and criticisms. Gruvies and Fries’ (1957) classification is in fact not a classification as it lacks categories and demarcations of errors, also because it is so broad and singular using it will likely lead to failing to capture some forms of error, lastly this classification does not appear to overlap well with Reasons (1990) framework of error. Leape et al.’s (1991) classification suffers primarily from complexity and appears to focus on active failures relating to drugs rather than the process of how errors happened rather than what type of errors happened to occur. And, Cooper et al.’s (1984) classification seems to be limited to highly detailed data sets for analysis.

## **Classification of Error in this Study**

In this investigation a preliminary review of research on human error in anaesthesia suggested that none of the previously mentioned classifications of error were applicable to permit a comparison between studies, therefore a custom classification was used. This custom classification was designed to reflect both the types of research available as well as Reason's (1990) theoretical concepts as much as possible. Human error was chosen to be investigated using clusters of active failures investigated in Cooper et al. (1984) that were found to be common within reviews of anaesthesia research (Dhillon, 2003). This classification consisted of ventilation and breathing circuit management errors, drug treatment errors, anaesthesia machine use errors, and airway management errors (see table 3). The classification of error used for this investigation noticeably differs from the previously mentioned classifications by its focus more so on active failures, therefore it poorly discriminates between errors of slips, mistakes or lapses, this limitation can be partially alleviated by investigating these causes in the following discussion.

Table 3.

*Classification of error used in this study*

<b>Type of Anaesthetic Error</b>	<b>Definition</b>
Ventilation and breathing circuit management errors	Any error in which the ventilation machine or associated devices intended to deliver oxygen are inappropriately used or configured.
Drug treatment errors	Any error in which drugs are erroneously prepared or administered. Some examples include incorrect timing of drug administration, incorrect dose, incorrect drug, and incorrect drug administration route.
Anaesthesia machine user errors	Any error in which incorrect actions occurred related to operating or managing the anaesthesia machine or where there was mismanagement of the delivery of anaesthetic gases.
Airway management errors	Any error in which the incorrect or inappropriate decision is made, or the incorrect technique is used, for maintaining a clear and safe airway for a patient during all stages of anaesthesia.

**Rates (incidence) of human error in anaesthesia**

Human error has been found to be a contributor to incidents in anaesthesia in a variety of research, for example Cooper et al. (1978) found human error to account for 82% of preventable critical incidents; Craig and Wilson (1981) found human error to account for 54%; Chopra et al. (1992) found human error responsible for 75% of incidents; Buckley et al. (1997) found human error to be involved in 55% of critical incidents; And in more recent times Gupta et al. (2009) and Kothari (2010) found human error to explain 65-85% of mortality in incidents, with Gupta et al. (2009) finding 40% of critical incidents being totally attributable to errors by the anaesthetist. These rates of error have been found to be similar in other research (Beckmann, Baldwin, Hart & Runciman, 1996; Cooper, Newbower, Long & McPeck, 1978; Dhillon, 2003; Kawashima et al., 2003).

Human error is understood to occur at various times or specific stages associated with specific tasks, these stages are typically referred to as induction, maintenance, and emergence with each describing tasks performed during the beginning, middle and end of operation (Fletcher, Flin & McGeorge, 2000; S Staender, Davies, Helmreich, Sexton & Kaufmann, 1997). Human error has been studied during these stages often as a secondary approach to analysing incident in anaesthesia (Fletcher et al., 2000; Gupta, Naithani, Brajesh, Pathania & Gupta, 2009). Induction has been found to be associated with up to 23% of incidents in anaesthesia (Fasting & Gisvold, 2000; Fletcher et al., 2000); Maintenance has been found to be associated with up to 47% of incidents in anaesthesia and has been suggested to be the most highly associated stage of anaesthesia with incident (Chopra et al., 1992; Fletcher et al., 2000; Gupta et al., 2009); and, emergence has in some research been found to account for as much as 43.75% of error (Gupta et al., 2009), but most researchers have found most errors to occur during maintenance or induction (Fletcher et al., 2000). Unfortunately because there is a limited amount of research on the stage of anaesthesia, and the findings may be largely dependent on the type of system employed in a specific country, there is a lack of research on which stage of anaesthesia is associated with error in New Zealand; therefore this investigation will examine this as the research question:

Research Question 1: When during anaesthesia does human error occur?

### ***Ventilation and Breathing Circuit Related Errors.***

Ventilation and breathing circuit errors, which describe any error in which the ventilation machine or associated devices intended to deliver oxygen are inappropriately used or configured, have been found to be associated with incident in anaesthesia. Ventilation and breathing circuit errors have been frequently cited as active failures where there is breathing circuit disconnections, misconnections, breathing circuit leaks, and circuit control errors (Dhillon, 2003; Weinger, 1999). Ventilation and breathing circuit errors have been found to explain 4-21.20% of incidents in anaesthesia from 1950-1990 (Beckmann et al., 1996; Cooper et al., 1984; Craig & Wilson, 1981; Kumar, Barcellos, Mehta, & Carter, 1988; Webb et al., 1993) and 8-10% of incident in more recent research (Hove et al., 2007; Kawashima et al., 2003; MacRae, 2007). This type of error is suggested to have declined as individual incidents are now reported as the main form of research (McLean, Houston & Dumais, 2003; Umesh, Jasvinder & Sagarnil, 2010). Ventilation and breathing circuit errors have been found to explain nearly 1/3rd of the most frequently cited contributors of incident in anaesthesia (Dhillon, 2003), in recent research ventilation and breathing circuit error has been suggested to have declined as more recent studies on incidents have focused on other types of error. Ventilation and breathing circuit errors have been suggested to occur infrequently, in more recent times, due to training and improvements in equipment design for detecting errors or problems (Buckley et al., 1997; Gaba & DeAnda, 1989; Kennedy & French, 2001). Ventilator control errors, specifically settings being entered incorrectly, have been cited in some research as the most frequent type of ventilation error (Kawashima et al., 2003).

Breathing circuit disconnections and leaks have been found to be due to slips or lapses (Cooper et al., 1984), however more information is needed on this subject and the causal mechanisms behind these errors.

Table 4.

*Critical incident reporting studies classified by the classification of this study*

Study	Time Period of Data	Percentage of incidents due to error	Percentage of error due to Ventilation or Breathing Circuit Error	Percentage of error due to Drug Treatment Error	Percentage of error due to Anaesthesia Machine Error	Percentage of error due to Airway Management Error
Cooper et al. (1978)	1975-1977	82%	19.5%	19%	19.5%	12%
Craig and Wilson (1981)	-	54%	8.6%	14.8%	44%	25.9%
Cooper et al. (1984)	-	64%	10.6%	23.6%	22.1%	15.7%
Kumar et al. (1988)*	1984-1986	80.3%	4%*	19%*	39%*	8%*
Beckmann et al. (1996)	1993	66%	-	25%	-	20.5%
Webb et al. (1993)	1994	-	-	31.5%	-	23.1%
Kawashima et al. (2003)	1994-1998	-	9.3%	27.9%	8%	31.2%
Buckley et al. (1997)	1993-1996	55%	26.3%	23.6%	-	50%
<p><i>Notes:</i> Please note that the error percentages for the four types of anaesthetic in most studies are based upon categorizing incidents which were clear to the reviewer. It is likely that some types of error are underestimated.</p> <p>*Kumar et al.'s study is notably an underestimate as 11% of anaesthetic errors that Kumar et al. reported could not be found. The values for the four types of error total to 70% as opposed to Kumar et al.'s report of 81%.</p>						

### ***Drug Treatment Error.***

Drug treatment error which describes any instance where a drug is inappropriately prepared or administered, has been found in various research in healthcare and anaesthesia (Cooper & Nossaman, 2013; Dhillon, 2003; Kohn et al., 1999; Tobias, Yadav, Gupta & Jain, 2013). Drug treatment error in recent research has been studied under many different frameworks such as in research investigating medication errors, adverse drug events (ADE), drug administration errors, dose errors, and adverse drug reactions (Wheeler & Wheeler, 2005). Drug treatment error in anaesthesia has been found to explain 19-40.2% of incidents in research (see table 4) and is estimated to occur in 0.75% of total anaesthetics in New Zealand (Gander, Merry, Millar & Weller, 2000) and 0.47-0.75% globally (Cooper & Nossaman, 2013). Drug treatment error has been found to consist of active failures including: errors in the selection of syringe before administration (syringe swap) and the vials containing drugs (ampule swap), drug overdoses and insufficient dosages, and other drug treatment errors such as mislabelling errors and infusion swap errors (Abeysekera, Bergman, Kluger & Short, 2005; Dhillon, 2003; Fasting & Gisvold, 2000; Webster, Merry, Larsson, McGrath & Weller, 2001). Syringe swaps have been found to be the most frequent type of drug treatment error in many studies (Abeysekera et al., 2005; Cooper et al., 1984; Craig & Wilson, 1981; Fasting & Gisvold, 2000) being associated with 23-37% of incidents in anaesthesia in recent research (Abeysekera et al., 2005; Yamamoto, Ishikawa & Makita, 2008). Ampule swaps have been found to account for 28% of drug treatment errors (Abeysekera et al., 2005), and ranking as the second most frequently common drug treatment error in

research (Abeysekera et al., 2005; Cooper et al., 1984; Dhillon, 2003). Drug overdoses and incorrect doses have been found to account for 20-23% of drug treatment error (Dhillon, 2003; Webster et al., 2001; Zhang et al., 2013). And, other types of drug treatment error such as ampoule mislabelling and incorrect drug administration have been found to explain up to 27% of drug treatment error (Abeysekera et al., 2005; Fasting & Gisvold, 2000). Syringe swaps and ampule swaps have been suggested to be due to slips as inattention, haste, and distraction have been found to contribute to them, both of these types of error have also been suggested to occur due to similarity in appearance between ampules and syringes (Abeysekera et al., 2005; Fasting & Gisvold, 2000). Drug overdoses have been suggested to be due to slips and mistakes in some research, some have suggested they may also be due to a tendency for anaesthetists to use an entire ampoule in a single dose (Abeysekera et al., 2005; Cooper et al., 1984). Drug treatment error in general has been suggested to be due to violations, or failures to check (Webster et al., 2001), why these occur is currently unknown. Unfortunately research is still somewhat unclear regarding the mechanisms behind these active failures, especially drug overdoses, this is an area of future needed research. New drug treatment systems are currently being tested and introduced, and have been found to significantly decrease drug treatment error (Webster et al., 2010).

### ***Anaesthesia Machine (Operator) Error.***

Anaesthesia machine errors which are described as any instance of incorrect operation or management of the anaesthesia machine, has been found to explain 8-

44% of anaesthetic error related incidents between 1950 -1990 (see Table 4).

Anaesthesia machine errors have been found to consist of active failures involving the misconnection of patients to the anaesthesia machine system, the control of the anaesthesia machine, errors ensuring there is always an adequate gas supply, and failures in detecting equipment faults prior to use (Blike & Biddle, 2000; Cooper, Newbower, Long & McPeck, 1978; Craig & Wilson, 1981; Ezike, Amucheazi, Ajuzieogu, Ufuegbunam & Achi, 2009; Fasting & Gisvold, 2002; Larson et al., 2007; Weinger, 1999). Erroneous misconnections of patients from the anaesthesia machine have been found to be the most frequent type of human error involving an anaesthesia machine in some research (Fasting & Gisvold, 2002). Gas flow control errors have been found to be the most common form of this error in research predating 1990, it has also been suggested that errors involving gas supply may be almost as frequent as misconnections of patients (Cooper et al., 1984; Dhillon, 2003). Failure to detect equipment faults have been found to occur with failure rates between 30-50% (Blike & Biddle, 2000; Ezike et al., 2009; Larson et al., 2007). Gas flow errors, failures to detect faults, and a variety of other errors have been recently found to contribute to incident (Cassidy, Smith & Arnot-Smith, 2011). Erroneous misconnections of patients from the anaesthesia machine has been suggested to be due to insufficient checks (Fasting & Gisvold, 2002), it is unclear currently if this is intentional, due to a mistake, or due to slip related factors. Gas control errors and gas supply errors have been suggested to be slips involving attention failures, such as similarities between gas control knobs (Weinger, 1999). Failures to detect equipment faults in respect to

its causes has not been thoroughly examined, this is currently an area needing future research.

### ***Airway Management Error.***

Airway management error, described as incorrect decisions or usage of technique for maintaining a clear and safe airway in patients, has been found to be associated with 8-31.2% of anaesthetic error in research predating 1990 (see Table 4), 17-50% of incidents in more recent research (Gupta et al., 2009; Kawashima et al., 2003), and up to 52.2% of incidents in paediatric anaesthesia (Marcus, 2006). The active failures of this type of error consists of premature extubation and endobronchial intubation (Dhillon, 2003). Premature extubation, which is inappropriate removal of an intubation device from a patient, has been found to explain a high proportion of airway related error in anaesthesia (Dhillon, 2003), one example is of Buckley et al. (1997) who found accidental extubation to explain 83.7% of total airway events and error. Endobronchial intubation describes intubation configurations used which fail to provide oxygen, they are sometimes also referred to in research as difficult intubation, 51% of these have been found to be due to human error (Uerpaiojkit et al., 2008). This type of active failure has been suggested to account for 3.7% of incidents in anaesthesia (McCoy, Russell & Webb, 1997).

Premature extubation has been suggested to be due in part to latent failures regarding staffing as a shortage of nurses for required observing has been noted in some research (Buckley et al., 1997), others have also suggested that mistakes contribute to this type of error (Cooper et al., 1984; Marcus, 2006). Endobrachial

intubation has been found to be due to slips, such as failures to perform a check (Cooper et al., 1984; Marcus, 2006). Airway management error in pediatric anaesthesia has overall been found to be due mostly to rule based mistakes (28%), latent errors (24.9%), knowledge based mistakes (15%), rule violations (14.5%), and slips (13.3%) (Marcus, 2006).

### **Conclusion**

Human error, which Reason (1990) described as failures of action or planning is understood to contribute to a high amount of incident in anaesthesia, somewhere between 50-80% of critical incidents. Across the examined types of error in anaesthesia (ventilation or breathing circuit related, anaesthesia machine related, drug treatment related, and airway management related), airway management error and drug treatment error are suggested to currently contribute to the highest amount of incidents involving human error, of which the cause has been suggested to be due to primarily slips for drug treatment and mistakes for airway management. Ventilation or breathing circuit management error and anaesthesia machine error have been suggested to occur rarely in current research.

### **Consequences and Costs of Anesthetic Error**

#### ***Mortality.***

Mortality is perhaps the greatest indicator of patient safety and human error in anaesthesia. Mortality in anaesthesia has been found to currently range from 0.12-1.40 deaths per 10,000 anaesthetics in developed countries and 3.3-5.7 deaths per 10,000 anaesthetics in undeveloped counties (Braz et al., 2009). This rate has been

suggested to be a large decrease from anaesthesia predating 2000 (Aitkenhead, 2005; Braz et al., 2009). Human error has been suggested to explain between 22.2%-28.75% of anaesthesia associated mortality in recent research (Gupta et al., 2009; Kawashima et al., 2003). Drug treatment errors and airway management errors have been found to explain 18.1% and 7.9% of mortality outcomes respectively (Aitkenhead, 2005), others have estimated drug treatment errors and airway management errors to explain 16.66-46.6% and 42% of fatal outcomes respectively (Cook, Scott, Mihai & Bland, L., 2010; Hove et al., 2007; Zhang et al., 2013). Mortality and major morbidity from drug treatment errors have been found to be due to active failures involving incorrect doses (31%), syringe swaps (24%), other types of drug errors (24%) and erroneous drug administration (unplanned) (17%) (Bowdle, 2003). Mortality from airway management error has been found to consist of incidents involving oesophageal intubation and endotracheal intubation, these have been suggested to be in part explained by human error as a large amount (60-80%) of standard of care has been found in these cases (Aitkenhead, 2005; Cook & MacDougall-Davis, 2012). Future research is needed regarding the role of human error in incidents involving airway management error. The contribution of human error to anaesthesia is unfortunately unclear currently as most research on mortality does not discriminate between deaths due to error and those that were not, therefore this investigation will examine the research question:

Research Question 2: What is the frequency and severity of human error in anaesthesia in New Zealand?

### ***Financial Costs.***

In addition to mortality is the financial burden involved when errors or mishaps occur in anaesthesia. Anaesthesia litigation has been found to be due to primarily drug treatment errors and airway management errors (Cook et al., 2010; Cranshaw, Gupta & Cook, 2009). Drug treatment errors have been found to explain 66.66% of anaesthesia litigation claims, which totalled to \$6.4 million USD over a 12 year period and airway management errors have been found to explain 35.8% of anaesthesia closed claims (Cook et al., 2010), which totalled to \$7.2 million USD. Airway management errors have been suggested to cost more due to deaths occurring more often (53%) than drug error (10.75%) and costs reflecting severity of incident (Cook et al., 2010; Cranshaw et al., 2009; Szypula et al., 2010).

In conclusion mortality in anaesthesia is highly represented by drug treatment error and airway management error. Some studies suggest that airway management explains similar or possibly higher mortality rates than drug treatment error. Drug treatment error and airway management error are estimated to cost healthcare providers at least around 2 million USD per year.

### **Contributors to Anaesthetic error**

As mentioned earlier, the SCM provides an understanding of how error occurs if there is an understanding of the latent failures currently within a system, some of these include the examples provided earlier such as staffing policies, adequateness of procedures, and inadequate supervision of trainees. The SCM suggests that the preconditions for unsafe acts (fatigue, stress and equipment design) represent the

latent failures closest to the event of an error or incident (see figure 1). Examining these factors can help researchers better understand how fatigue, stress and equipment design contribute to human error in anaesthesia.

### **Fatigue**

Fatigue is one type of latent risk within the SCM existing at the pre-conditional level, increasing risk by deteriorating the physical and mental condition of operators, this has been suggested as the primary link between fatigue and error in research (Gregory & Edsell, 2013). Mental degradation from fatigue has been suggested to be due to temporary disruptions (micro-sleeps) which occur naturally as a result of the body attempting to initiate the natural sleep process in individuals who are sleep deprived (Durmer & Dinges, 2005). Fatigue has been found to explain 16-22% of medical errors in critical care (Landrigan et al., 2004; Sarani & Alarcon, 2005) 5-8.6% of errors in critical incidents in anaesthesia and at least 4.4%-12% of drug treatment errors such as active failures including: syringe swaps, ampoule labelling errors, drug preparation errors, and other drug related errors (see Table 5).

*Table 5. Frequency of fatigue cited as a contributor of error*

Source	% of incidents related to fatigue
Cooper et al. (1978)	6.69%
Craig and Wilson (1981)	8.64%
Cooper et al. (1984)	5%
Buckley et al. (1997)	7.40%
Webster et al. (2001)	9%
Abeysekera et al. (2005)	11%
Webster et al. (2010)*	6.3%

Fatigue unfortunately has generally not been studied extensively within studies on critical incidents in anaesthesia. In the limited studies available that do, fatigue has been reported by anaesthetists as a reason for significant medical error within their lifetime (Gander et al., 2000). The lack of studies currently demonstrating a relationship between fatigue and error in anaesthesia is surprising given researcher and anaesthetists agreement that it is a current problem (Merry & Warman, 2006; Sinha, Singh & Tewari, 2013; Wartier, Howard, Rosekind, Katz & Berry, 2002), this is an area of future needed research. This thesis will examine that relationship by answering the research question:

Research Question 3) How does fatigue contribute to human error in anaesthesia?

### **Stress**

Stress is one type of latent risk within the SCM at the pre-conditional level, acting by deteriorating the physical and mental condition of operators. This investigation will focus exclusively on the deterioration of mental conditions of operators as a result of stress. Stress is a well-recognized contributor to human error in high risk industries (Driskell & Salas, 1996), being associated with a high amount of drug treatment error outside of anaesthesia (Shanafelt et al., 2010). Stress has been defined as an “agent, circumstance, situation or variable that disturbs the normal functioning of an individual” (Staal, 2004, p. 1). The mental deterioration of operators that occurs as a result of stress has been suggested to be due to stress reducing the amount of information and the information processing efficiency of

individuals, these have been suggested to increase the chance for mistakes (Staal, 2004). Stress has been found to explain 10.44-12% of drug treatment errors, consisting of wrong drugs being administered or incorrect doses being used (Buckley et al., 1997; Webster et al., 2010, 2001). Anaesthetists have also reported being more likely to make an error when in a stressful situation (70% agreement) (Sexton, Thomas & Helmreich, 2000). Unfortunately research on the relationship between stress and human error in anaesthesia is currently scarce. This thesis will examine the relationship between stress and human error in anaesthesia by answering the research question:

Research Question 4) How does stress contribute to human error in anaesthesia?

### **Equipment Design**

Equipment design is one type of latent risk in the SCM at the pre-conditional level existing as a result of the technological environment anaesthetists operate within being inadequately designed to accommodate for anaesthetists needs or behavioural patterns (Norman, 2013). Equipment design related latent risks have been suggested to be due to equipment possessing characteristics that can increase human error, as well as the severity of it; Arnstein (1997) provides an example of this as wrapping materials used for intubation tubes sometimes exhibit poor packaging design, this can lead to problems opening or pieces of plastic being unnoticeably caught within the tube, making it potentially deadly for patients. Poor usability design has also been suggested to contribute to error (Nielsen, 1993), these types of errors occur according

to Norman (2013) as a result of equipment design exhibiting characteristics that are perceived by users as confusing or misleading. Some examples of these include unclear, unintuitive, or complicated controls, user interfaces, monitors, labels, or workstation layouts (Arnstein, 1997; Webster et al., 2010; Weinger, 1999). Poor usability has been found to explain 41% of drug prescription errors in other fields (Kushniruk, Triola, Borycki, Stein & Kannry, 2005), these errors have been suggested to also occur in anaesthesia (Kothari et al., 2010). Within anaesthesia, 25% of incidents reported as being due to equipment failures have in fact been found to be due to human error, such as in anaesthesia machine error and inadequate pre-use checks (Fasting & Gisvold, 2002). Equipment design has been found to be one of the most frequent contributors to error in some research, often this research cites equipment design problems regarding patient monitoring devices during procedure (Cooper et al., 1984; Weinger & Slagle, 2002). Currently, new anaesthesia drug delivery systems are being studied, one of these is Webster et al.'s (2010) SAFERsleep system which has been found to be associated with fewer drug treatment errors (0.032%) than conventional drug treatment systems (0.049%) per anaesthetic. Their system emphasizes usability design principles by having a clear labelling of drugs, using colour coding to reduce the selection of the incorrect class of drug, computerized check of drugs, and using organized workspace with unique equipment and designated work zones to help reduce clutter and confusion that may contribute to error. Unfortunately the research on equipment design latent risks in anaesthesia is limited, this thesis will examine this gap in the literature by answering the research question:

Research Question 5) How does equipment design contribute to human error in anaesthesia?

### **Research Questions and Approach**

In this thesis's examination of human error in anaesthesia five questions were raised based upon gaps in the current body of research and the importance of applying the SCM within anaesthesia, these questions were:

Research question 1. When during anaesthesia does human error occur?

Research question 2. What is the frequency and severity of human error in anaesthesia in New Zealand?

Research question 3. How does fatigue contribute to human error in anaesthetic procedures?

Research question 4. How does stress contribute to human error in anaesthetic procedures?

Research question 5. How do usability problems contribute to human error in anaesthetic procedures?

Most of the research questions raised relate specifically to identifying a relationship between latent risk factors within the SCM that have been identified in literature that exist at the pre-conditional level in anaesthesia and human error. These research questions, if answered, could provide a clear explanation of how these latent risk factors lead to active failures that cause harm to patients, this is the intention of this investigations design.

The approach chosen for answering these research questions consists of a two-stage investigation involving documentation of anaesthesia procedures and later a collection and analysis of information regarding human error and incident. The purpose of this two stage investigation is to collect necessary information that could alter the methodology used later to answer this investigation's research questions.

The first stage is dedicated to documenting the anaesthetic process, as this will help the researcher identify human errors that might not have been commonly identified in previous literature or might be seldom reported in recent research, such as pre-operative room errors. This stage is also intended to provide the researcher with adequate subject knowledge to construct a tool which will allow for the collection of incident and human error data that will allow an analysis which will provide answers to the raised research questions. Increasing subject knowledge may also increase the reliability of the analysis.

### **Summary**

This thesis will use a two stage process in which documentation, incident information, error information and analysis will assess the contribution of latent risk factors at the pre-conditional level, their impact on patients and the additional research questions raised. The next two chapters describe the process, results and findings for each stage of this investigation. This investigation will then conclude with a chapter which provides an overall discussion.

## **Chapter 2. Stage 1-Documenting the anaesthetic process**

The first Stage of this investigation consists of documenting the anaesthetic process. This Stage was necessary because it would increase subject matter knowledge and information on the process of the general anaesthetic, these were important because they could enhance the methodology to be used in the second stage of this investigation. Subject matter knowledge is useful because it would help demarcate errors from non-errors, aid in identifying which tasks are associated with which stage of the anaesthesia and possibly provide other information related to the research questions. Stage 1 consisted of a collection of preliminary incident information and analysis achieved by interviewing anaesthetists using Stanton et al.'s (cite) task analysis (TA) and Flanagan's (1954) critical incident technique (CIT). TA is a process in which "tasks are identified, task data is collected, and analysed so that tasks (and errors) are understood, and then a documented representation of the analysed tasks is produced (Stanton et al., 2003, p. 36). This would allow for collection of information on the anaesthetic process. The CIT is a retrospective data collection process in which prepared questions are designed to target specific behaviours, it was used with the intention of producing information on human errors that were associated with critical incident such as active failures, contextual information, equipment design problems, and information on incidence of frequency and severity.

## **Method**

### **Participants**

Two participants were recruited, one participant was from a DHB and the other was from a private practice being recruited through a student referral. The participant from the DHB was an anaesthetist consultant with at least 5 years of training and the participant from private practice was a senior anaesthetist with at least 15 years' experience. Participants did not receive any incentive for their participation. This procedure was given ethics approval by the University of Waikato's School of Psychology.

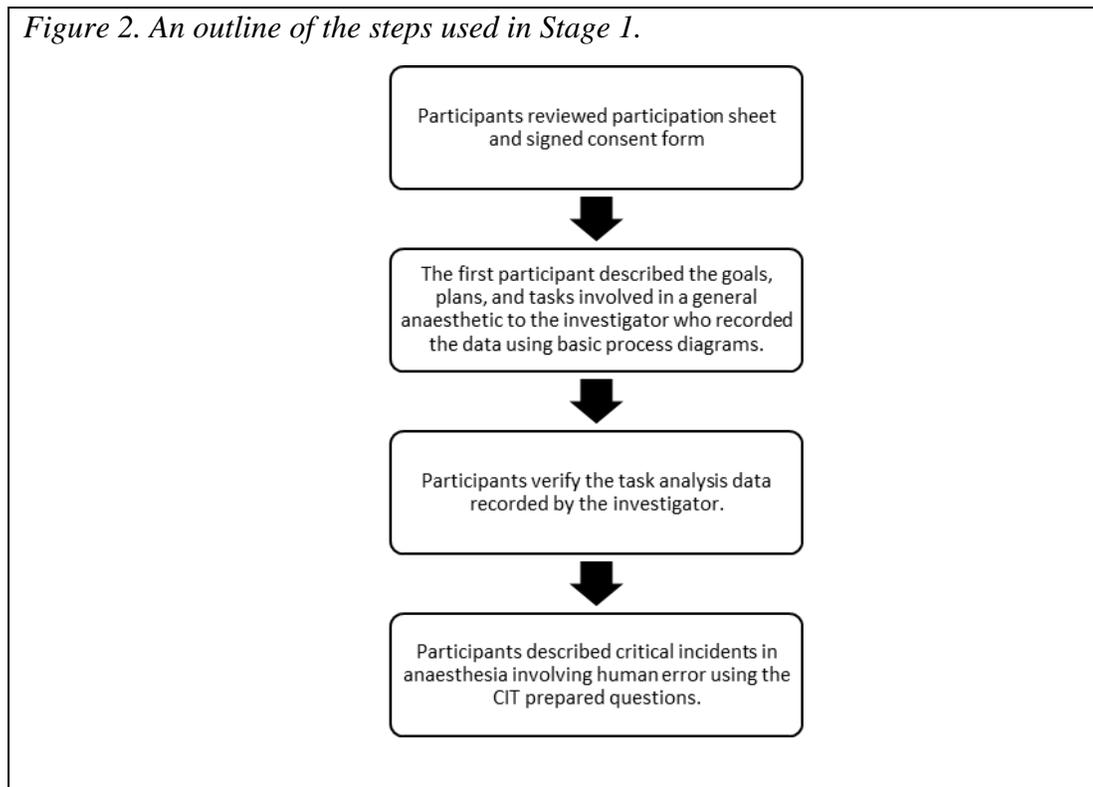
### **Materials**

For Stage 1, basic process diagrams from Microsoft Word were used for TA and prepared questions were used for CIT. The prepared questions for CIT targeted active failures, contextual information, equipment design latent failures, and ratings of incident frequency and severity. The rating system used for incident frequency and severity was derived from Fasting and Gisvold (2002), these questions and materials can be seen in Appendix A.

### **Procedure**

Participants were instructed to review a participant information sheet which highlighted the background of the study, the requirements of them for the study, and their participation rights (see Figure 2). If participants agreed to these terms they signed a consent form for the study. The first participant was instructed to describe

the goals, plans and tasks involved in a routine general anaesthetic, this information was recorded on basic process diagrams by the researcher and then verified by the participant for accuracy regarding the tasks, goals, and plans recorded in terms of content and sequence. The second participant was instructed only to verify and amend same process diagram obtained from the first participant.



Participants were then asked prepared questions (see Appendix A and B) with the instruction of recalling critical incidents in anaesthesia involving human error, participant responses were recorded that were related to identifying the active failure, stage the anaesthesia human error occurred, equipment design latent failures, and participants' rating of the incident's frequency and severity. Participants were asked

supplementary questions when needed to verify that incidents involved human error, cases which did not were excluded from recordings.

## **Results**

### ***Task Analysis.***

6 goals were found to explain the work process of a general anaesthetic, each goal was comprised of a variety of tasks and sub tasks, the sequence of which was determined by a set of plans. The 6 goals were (in sequential order) conducting “pre-induction checks”, transporting patients into the operating room, sedating and stabilizing patients (induction), maintaining sedation in a stable condition (maintenance), preparing patient for waking (emergence), and transporting patients out of the operating room; of these goals pre-induction, induction, maintenance, and emergence can be considered stages of anaesthesia.

The first plan found determined the process used for the entire anaesthetic, plans 2-9 describe the sequence in which tasks should be performed, and plans 3,4,6,8 and 10 describe the subtasks of the anaesthetic process, all this can be seen within a hierarchical task analysis shown in Figures 3 and 4. Descriptions of the major tasks, their associated tasks and plans can be found below described by the stage of anaesthesia they occurred in, a hierarchical task analysis representation of these tasks can be found on Figure 3 (pre-induction checks and induction) and Figure 4 (maintenance and emergence).

*Pre-induction checks.*

The first series of tasks and subtasks in anaesthesia found were a variety of checks occurring before induction, these subtasks are collectively referred to as pre-induction checks. Anaesthetists are required to acquire patient information (1.1) this required accessing a medical database which already had adequate patient information, or by examining a patient before operation, this was necessary to help the anaesthetist plan for appropriate drug treatment and airway management. The anaesthetist would then make preparations for drug treatment (1.2) by selecting the necessary drugs, drawing the correct doses based on planned calculations, and ensuring access to emergency drugs. Anaesthetists would then verify patient's identity, their consent to the operation (1.3), and a consultation with operating staff regarding complications would be required along with an equipment check (1.4), then an intravenous line in the patient would be prepared (1.5) and the patient would be transported to the operating room (2).

Figure 3. A Hierarchical Task Analysis using Stanton et al.'s (2003) process of the first two stages of anaesthesia

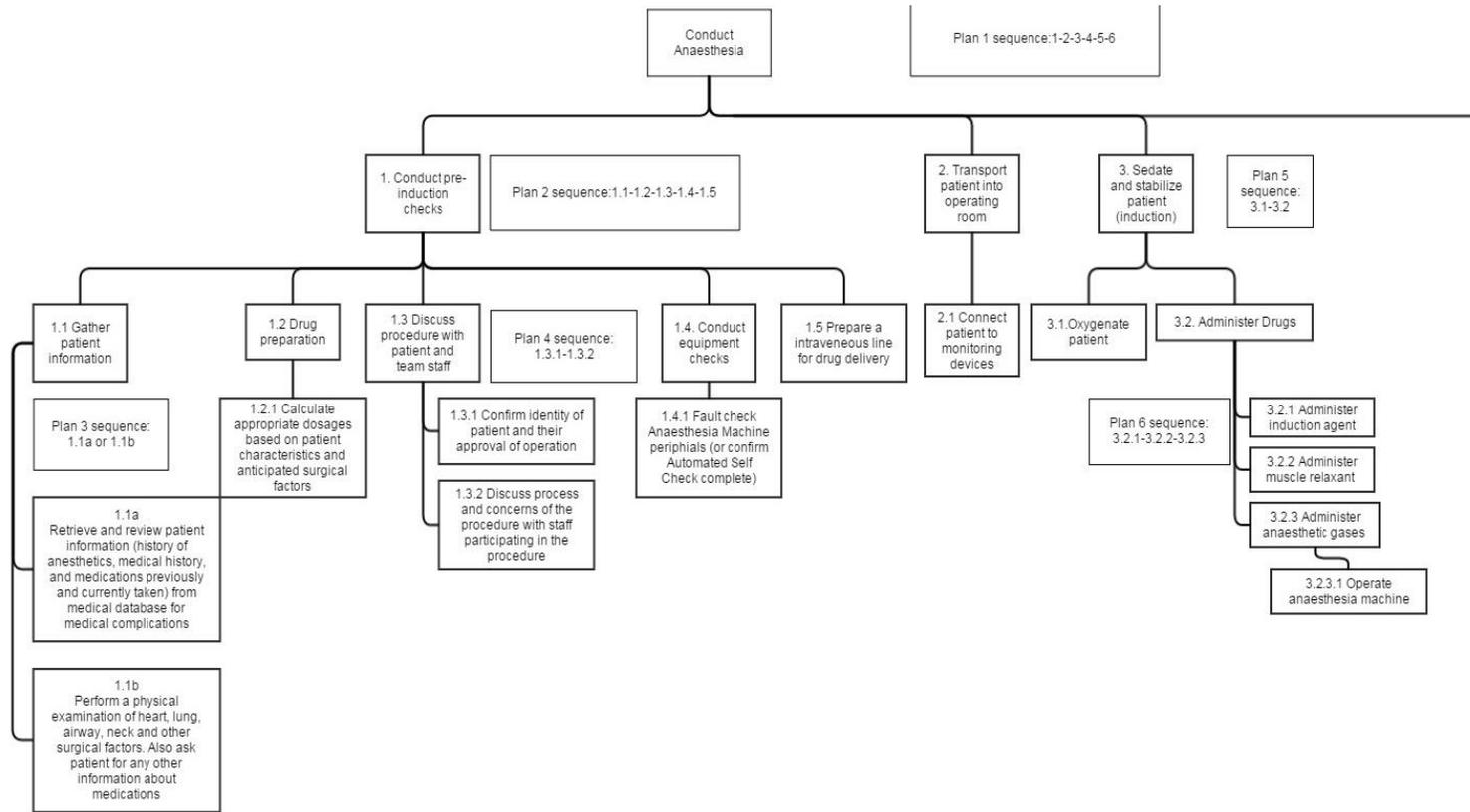
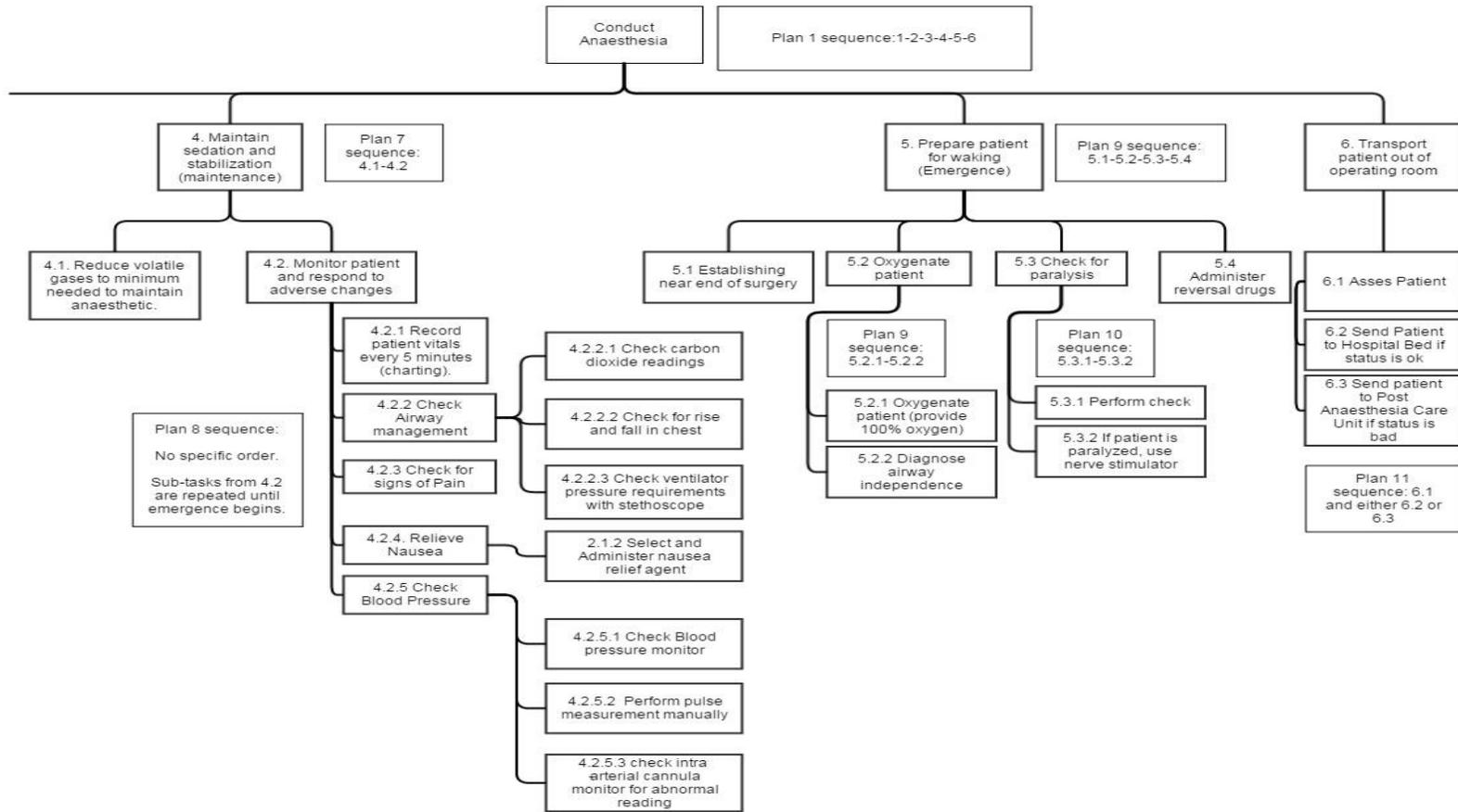


Figure 4. Hierarchical Task Analysis of the anaesthetic continued.



### *Induction.*

The second series of sub tasks and tasks in anaesthesia are concerned with induction. The purpose of induction is to provide patients unconsciousness, pain relief, amnesia of operation, and relaxation of muscles of the body (Anderson, Anderson & Glanze, 2002). Induction was found to begin with the anaesthetist supplying an adequate amount of oxygen to patients (3.1), sedating patients by administering an induction agent (3.2.1) followed by a muscle relaxant (3.2.2). Anaesthetists then have to program the anaesthesia machine to provide precise amounts of volatile (inhaled) anaesthetic gases at a controlled rate to prolong and control sedation of the patient (3.2.3). Although not depicted in Figure 3 the method of programming the anaesthesia machines was found to differ with the electronic anaesthesia machine system using a control dial that would require turning and pressing a confirmation button to verify changes, while the analogue anaesthesia machine system's control dial produced immediate effect, when turned, without need for verification.

### *Maintenance.*

After induction is completed anaesthetists must program the anaesthesia machine to lower the amount of volatile anaesthesia gases to low levels required to maintain an anaesthetic state (4.1), this marks the beginning of the maintenance phase in which they perform a variety of sub tasks related to maintaining the anaesthetic state. The purpose of maintenance is to ensure that patients do not experience harm by monitoring patient vitals for any anaesthesia risk factors continuously and taking appropriate action, to accomplish this anaesthetists are required to perform

continuous checking of the patient for airway problems (4.2.2), symptoms of pain (4.2.3), nausea (4.2.4) and adverse blood pressure (4.2.5) until the end of surgery, these kinds of information must also be recorded on the anaesthetic chart every 5 minutes (4.2.1). When problems do occur anaesthetists are required to perform the appropriate check and take the correct action, in instances of pain, nausea, or adverse blood pressure change, administration of a drug may be required, in problems related to airway management diagnosis, intubation attempts or emergency methods may be required (see Figure 4, plan 8).

#### *Emergence.*

The final tasks for the anaesthetic are those which are collectively referred to as emergence tasks. The purpose of emergence is to prepare the patient for waking at the conclusion of surgery, anaesthetists accomplish this by confirming the end of surgery (5.1), providing patients with an adequate supply of oxygen and assessing their ability to breath without aid (5.2), checking the patient for muscle paralysis (5.3), and administering anaesthesia drugs which would reverse the last effects of sedation (5.4). Afterward, dependent on patient assessment (6.1), patients are transported to either a hospital bed (6.2) or a post anaesthetic care unit for future monitoring (6.3).

#### *Critical Incidents.*

Human error information was tabulated using the stages of anaesthesia obtained during TA as the rows and the equipment used during incident and it's mode of use, type of error, and frequency and severity of the incident as the columns (see

Table 6 and 7). Information from incidents are analysed below using Flanagan's (1954) critical incident analysis.

*First Participant results.*

The first participant described 4 incidents, two of these occurred prior to induction and the other two occurred during induction. The first incident that occurred prior to induction was an active failure regarding breathing and ventilation, the error in this incident was a failure to check the oxygen supply before usage, during the anaesthetic this became apparent by a loss of oxygen in the patient observed. This incident was not reported to have any effect on the patient. The second incident that occurred prior to induction consisted of an anaesthesia machine error, the error in this incident was the anaesthetist technician's failure to check the machine, this incident was also rare and of no harm to the patient.

The first incident that occurred during induction was a drug treatment error in which a drug was prepared incorrectly, the error was of the anaesthetist placing the incorrect type of label on the syringe, this led to the anaesthetist administering the incorrect drug. This incident was of judged to be of low severity with the patient requiring a short stay in the post anaesthetic care unit, this incident was reported to occur rarely. The second incident that occurred during induction was a drug treatment error involving the infusion pump connected to the syringe, the error was that there was an incorrect amount of drug being selected with the infusion pump controls, and this was explained as being due to a difficulty in reading the rate of drug delivery and

in selecting or confirming drugs. The incident involving the infusion pump was of no effect and was reported to occur rarely.

Table 6.

*Critical incident information from Participant 1*

<i>Stage of anesthesia</i>	<i>Equipment (and mode of use if available)</i>	<i>Problem/error</i>	<i>Explanation of problem</i>	<i>Effect on patient</i>	<i>Severity/Frequency</i>  (1=low, 3=high)	<i>Number of times reported</i>
<i>Pre-Induction</i>	<i>Oxygen main supply</i>	<i>Oxygen supply depleted.</i>	<i>Failure to check tube in-between anesthetics.</i>	-	1/1	1
	<i>Gas machine administering volatile gases.</i>	<i>Incorrect tubing in anesthetic gas machine led to reduction in gas concentrations.</i>	<i>Anaesthetist technician failed to perform a fault check.</i>	-	1/1	1
<i>Induction</i>	<i>Drug container and syringe</i>  <i>Mode of use: drawing/drug preparation</i>	<i>Drew incorrect drug (paralysis class drug switched with relaxant)</i>	<i>Sticker on syringe did not match drug in syringe.</i>	<i>Minor increase in time spent in operation to reverse the drug effect.</i>	1/1	1
<i>Maintenance</i>	-	-	-	-	-	-
<i>Emergence</i>	-	-	-	-	-	-

*Second participant.*

The second participant described 3 incidents which all occurred during induction. Two of the incidents were found to be drug treatment errors, these errors involved the active failures of incorrect drug administration and incorrect doses being used. The incident involving incorrect drug administration led to an incident of high severity with the patient suffering anaphylaxis and requiring time in the post anaesthetic care unit as a result of error. The other drug treatment error involved an inadequate amount of drug being used; this was reported to be of no harm and low

frequency. The other incident that occurred during induction was an anaesthesia machine error, the error in this incident was the anaesthetist technician's failure to check the anaesthesia machine prior to use. This incident resulted in no harm and was of low frequency.

Table 7.

*Critical incident information from Participant 2*

<i>Stage of anesthesia error occurred in</i>	<i>Equipment (and mode of use if available)</i>	<i>Problem/error</i>	<i>Explanation of problem</i>	<i>Effect on patient</i>	<i>Severity/Frequency (1=low, 3=high)</i>	<i>Number of times reported</i>
Pre-Induction	-	-	-	-	-	-
Induction	Syringe, Intravenous Injection.	Administrating the wrong drug (different class of drug)	-	Patient experienced Anaphylaxis and had to spend time in post anaesthetic care unit	3/1	1
	Gas machine administering volatile gases.	Incorrect tubing in anesthetic gas machine led to reduction in gas concentrations.	Anaesthetist technician failed to perform a fault check.	-	1/1	1
	Syringe, Intravenous injection	Inadequate drug amount of given	-	-	1/1	2
Maintenance	-	-	-	-	-	-
Emergence	-	-	-	-	-	-

**Discussion**

The purpose of Stage 1 was to collect information on the process of an anaesthetic, information on how human error can be classified and other information which could improve the design of the methodology to be used later for a larger scale collection of human errors in anaesthesia. Task analysis helped to establish the

various ways in which human error could occur in anaesthesia such as in the various tasks associated with each part of the process of anaesthesia, these were found to be primarily in the form of checks of various sources such as with the anaesthesia machine and drug treatment prior to induction, drug treatment during induction, drug treatment and airway management during maintenance, and drug treatment during emergence. The critical incident analysis helped identify some examples of recent errors in anaesthesia, it suggested that drug treatment error is perhaps the most common type of error and that there are various equipment that are associated with error such as the drug labels or infusion pump. Critical incident analysis also suggested that most incidents were of low severity and low frequency.

The information from Stage 1 suggested that open ended questions for describing error during incident would be potentially useful for the questionnaire used in Stage 2 because anaesthetists appear to also remember contextual information that helps researchers better understand the active failure, the causal mechanism behind it, and any latent failures that might have been present. These sorts of information might be more difficult to capture using closed questions. The criteria used for severity and frequency in this Stage, while demonstrating some differences, could have been improved by using objective criteria such as a reference for time for frequency, and more levels for severity, this is important because most incidents were found to be of “low harm” and “low severity”, had more levels for severity and frequency been used more meaningful differences might have been found such as whether or not an error was a near miss, this would be incorporated into the later questionnaire. And, responses from the equipment design related questions suggested

that usability problems do exist in current anaesthesia and that open ended questions should be used in the later questionnaire as they may capture more of this information as there is a large amount of technologies used within anaesthesia and there may be large differences between equipment used by staff of different facilities.

### **Chapter 3. Stage 2- Incidence and sources of anaesthetic error in New Zealand**

Stage 1 findings suggested that currently critical incidents in anaesthesia consist of drug treatment errors and anaesthesia machine errors which are typically of low harm, occur rarely, occur during induction, and in some rare cases might be partially due to equipment design problems. Unfortunately Stage 1 provided no information about the role of fatigue or stress in these critical incidents. Stage 1 helped clarify some of the characteristics needed in the questionnaire design in Stage 2, these were the usage of open ended questions for describing human error, usability, and possibly other topics relevant to the research questions of this investigation; Also during stage 1, incidence and severity measures were found to be inadequate and could be improved by using more objective and varying levels of description.

Stage 2 consists of creating and administering a questionnaire that would collect information which could answer the research questions of this investigation. The information needing to be obtained was data on the types of human errors in current incidents, the frequency and severity of these incidents, identification of equipment related to incident, descriptions of usability problems, and ratings of stress and fatigue during incident.

#### **Method**

##### **Participants**

12 Participants volunteered for this study from the Counties Manakau District Health Board (DHB) and the Whanganui DHB in New Zealand. Participants were mostly experienced, being registered in anaesthesia with at least 3 years of experience

(76.9%) with the remainder being current trainees (23%). 8 Participants completed all questionnaire items, and 4 provided partial responses. Partial data was kept and used for their respective analyses. The sampling rate for this study was 1.2% of the entire New Zealand anaesthetist practicing population according to the Medical Council of New Zealand which estimated the number of anaesthetists in practice at the time of this study at roughly 1000 practitioners (A. Cullen, Personal Communication, September 23, 2014.). This sample size is not similar to those used in other studies on critical incident in anaesthesia, however according to Flanagan (1954) there is no requirement for a set sample size for using the critical incident technique, rather the quality of incidents found and analysed are of main importance. The procedures and materials used for this Stage were given ethical approval from the School of Psychology's Research and Ethics Committee at the University of Waikato.

### **Materials**

This study used a questionnaire designed to qualitatively and quantitatively measure human error and the relationship between it and latent risks in anaesthesia (see Appendix C). The questionnaire consisted of two sections, one section related to collecting information on human error associated with a critical incident, this included information on the frequency and severity of the incident, a description of the error, and identification of when the error occurred; and the second section related to collecting information on related to fatigue, stress, or equipment design latent failures during incident. Please note that the order in which these sections are described are not the same as used in the questionnaire, this is because some

questions did not relate specifically to critical incidents and because questions were intentionally sequenced to enhance recall of information. For example, usability questions were asked immediately after participants identified the type of equipment they used during incident. This questionnaire was created and administered using Qualtrics software ([www.Qualtrics.com](http://www.Qualtrics.com)) and was pilot tested using 4 testers before finalization.

The first section, or the human error information section, consists of 5 questions, one of these was an adaption from Cooper et al. (1984) and the remainder was custom made. The question adapted from Cooper et al. (1984) was designed to identify when during the anaesthetic process incident occurred, this question was multiple choice with 6 levels (“pre induction”, “during induction”, “beginning of procedure”, “middle of procedure”, “end of procedure” and “after procedure (still in operating room)”). This item was used because it directly examined the stage of anaesthesia in which incident occurred and it featured a high amount of levels to observe differences with. The 4 custom questions consisted of 1 qualitative question and 3 quantitative questions. The single qualitative question was an open ended question asking participants to describe an incident involving human error and to identify the human error. The 3 quantitative questions consisted of 2 multiple choice questions using 5 levels, and a single multiple choice question using 2 levels which were used to describe the frequency and severity of error. All custom questions in this section were used because there was a lack of standardized or previously published questionnaires which described the frequency and severity of incidents in anaesthesia.

None of the previously mentioned questions have been psychometrically validated, only Cooper et al.'s (1984) adaption has been featured in any research.

The second section, or the latent risk factor section, consisted of 15 questions which related to fatigue, stress and equipment design latent failures during incident. Fatigue was measured using Samn-Perelli's (1982) single item assessed on a 7 point Likert scale which indicates impairment with responses ranging from "Fully Alert" to "Completely Exhausted". This measure has been validated with research indicating a reliable correlation between the measure and fatigue factors, in addition to exhibiting independence from measures of sleepiness (Gander et al., 2013; Samn & Perelli, 1982). Stress was measured using a custom 5 level scale where individuals rated the amount of stress they experienced during the incident with 1 indicating no stress and 5 indicating extremely high amounts of stress. This measure was used to provide a measure of stress, it has not been psychometrically validated. Cognitive interference was measured using an adaption of Stawski and Mogles' (2011) short cognitive interference measure, this was a single multiple choice item with 7 options which allowed multiple answers to be selected, each option described a symptom of cognitive interference. This measure has been validated with an overall reliability of 0.79% (Stawski et al., 2011). This measure was used because it has been suggested to be a primary part of how stress contributes to error (Stawski et al., 2011). Equipment design was assessed using 12 questions. One question was a single multiple choice item adapted from Cooper et al. (1984) which used 9 options to identify the type of equipment associated with incident, this item has been used in previous anaesthesia related research (Cooper et al., 1984). 10 multiple choice questions were used from

an adaption of Brooke et al.'s (1996) System Usability Scale (SUS), these adaptations differed from those featured in the SUS by the usage of the term "system" in place of "product". These 10 items were assessed on a 5 point Likert indicating agreement with statements regarding high or low usability such as "I thought the system was easy to use". The SUS was chosen as it has been found to be a valid measure of usability with a cronbach alpha of 0.911 (Bangor, Kortum & Miller, 2008). And 1 custom open ended question was used to identify any specific usability problems which might have not been covered by the SUS, this question has not been validated or featured in other research.

In addition to the core sections of this questionnaire there were also other questions which allowed the capture of related secondary information on fatigue, stress, and usability. This section consisted of 21 questions from O'Driscoll's (2000) social support (SS) measure, Cohen et al.'s (1983) perceived stress scale (PSS) and custom creation. O'Driscoll's (2000) social support (SS) consisted of 4 multiple choice items assessed on a 6 point Likert indicating the level of perceived social support they experience in the workplace, this measure was included because social support has been suggested to mitigate the impact of stress (Folkman & Lazarus, 1984; Lazarus, 1966). This measure has been validated with a Cronbach alpha of 0.91 (Chang, 2009). Cohen et al.'s (1983) PSS consisted of 10 multiple choice items assessed on a 5 point Likert indicating the level of stress experienced in life, this measure was used to provide a measure of chronic stress, it has been validated with a Cronbach alpha of 0.85 (Cohen et al., 1983). The qualitative custom questions consisted of 4 open ended questions which targeted times in the workplace where

there was a lack of stimulus, high effort, and job stress. These were created to provide contextual information on why violations and errors may also occur. These questions have not been validated or used in any previous research. The single quantitative custom question was multiple choice with 4 levels indicating level of experience, this was used as an indicator of the demographics of this study, gender was chosen not to be used in this regard because it might have led to identifying participants if only a small single hospital had agreed to participate.

### **Procedure**

Recruitment materials (see Appendix D) were sent by email to research or anaesthesia management departments in District Health Boards (DHBs) in New Zealand, 2 DHBs (Counties Manakau DHB and Whanganui DHB) agreed to send these materials to their anaesthetists. Informed consent was acquired by participants agreeing to the terms of participation (see Appendix E) which could be accessed through the recruitment materials sent to them, this allowed participants to begin the questionnaire after they provided informed consent.

Participants began the questionnaire being informed of the topics covered in the questionnaire and were advised that the questionnaire was intended only for anaesthetists. Participants were first asked a demographic question related to their job experience. Participants were then provided with the instructions and sets of questions for O'Driscoll's SS and Cohen's PSS. Participants then answered open ended questions relating to stress and fatigue within the workplace. Participants then answered questions relating to critical incidents, this began with an open ended

question asking them to describe an incident, followed by equipment design related questions, and finishing with fatigue and stress related questions, at the end of this participants were then asked if they wanted to report another critical incident, if they indicated they did another set of critical incident questions would be asked, if they indicated they did not they went to the end of the questionnaire. Participants were only given one chance to report another incident. At the conclusion of the questionnaire, participants were thanked for their participation and were notified on how they can request a copy of the summary of the results of this study.

## **Results**

Data was analysed using Flanagan's (1954) critical incident technique, this consisted of classifying critical incidents and providing functional descriptions of events for analysis purposes. For classifying critical incidents the classification of this investigation was used in addition to Reason's (1990) framework of error and SCM concepts. Incidents were classified and analysed in relation to information on their frequency, severity, stage of anaesthesia involved, fatigue, stress and equipment design.

### ***Frequency and severity of incident.***

A total of 8 incidents were found, these consisted of 1 incident which resulted in moderate harm reported to occur rarely (once per 2-3 months), 1 incident of small harm reported to occur almost never (few times in lifetime), and 6 incidents related to no harm but were classified as near misses, of these 4 were reported to occur rarely and 2 were reported to occur almost never. No incidents were found to occur very

commonly (once per week), commonly (once per 2 weeks), or uncommonly (once per month); also, no severe or fatal incidents were reported. Of the 8 incidents, 6 were found to still occur.

### ***Stage of anaesthesia error occurred in***

The single incident which resulted in a moderate amount of harm involved a failure to check that the blood pressure cuff had cycled during the middle of the procedure, this was due to a slip which was the result of task switching and multi-tasking which occurred due to a change in patient status (patient had begun haemorrhaging). According to the participant the blood pressure cuff must be checked at least every 5 minutes.

The single incident which resulted in a small amount of harm involved the use of the wrong technique (laryngeal mask airway used instead of guedel airway) on a patient during induction. This error was described as being caused by a mistake due to “poor recording of [the] actual problems the day before [leading] to a false sense of security”. This incident resulted in patient awareness and had potential for serious harm, as according to the participant “the incident was very close to needing [a] surgical airway”, this would have been very difficult in their patient as they had an obese, swollen, burnt neck.

The near misses reported to occur rarely involved an incident of breathing and ventilation error, drug treatment error, airway management error, anaesthesia machine error, and breathing and ventilation management error. The incident involving drug treatment error involved the drawing of the incorrect drug, this

occurred prior to induction and was caused by distraction due to a conversation between staff; Airway management error consisted of a premature extubation of a baby during the end of procedure, this occurred because of patient and surgical factors such as an abnormal airway, previous airway surgery, and poor timing of the surgery; anaesthesia machine error consisted of a failure to confirm an action on the anaesthesia machine specifically involving selecting the desired end tidal volatile concentration at the beginning of the procedure. This error occurred due to a lapse in memory regarding the requirement to confirm changes before they occur; and ventilation and breathing management error consisted of a failure to replace a carbon dioxide absorber during induction, this occurred due to a failure to perform a check (of a replacement) before there was a change of the attending anaesthetist.

The 2 incidents of near misses that were reported to almost never occur were found to consist of 1 drug treatment error, and 1 other type of error. The incident of drug treatment involved the administration of the incorrect drug during induction, this was caused by labelling differences between the attending anaesthetist and the anaesthetist who had originally labelled the drug and left shift. The other type of incident found involved an error related to monitoring devices, specifically a non-invasive blood pressure monitoring device, the error was a failure to switch the mode from manual to automatic during the beginning of the procedure.

### ***Contribution of fatigue to error***

Fatigue was found to contribute to half of the incidents investigated; this was indicated by a fatigue rating equivalent to being “a little tired” or worse. These

incidents included the moderate harm incident which involved a failure to perform a check, and near miss incidents involving drug treatment errors, airway management error, and an error using a monitoring device. In one incident, the one involving airway management error, fatigue latent risk factors were described by the participant such as the prevalence of a long shift (12 hour shift), the absence of a work break, working late at night, and having a high workload (high case list). In these incidents, three out of four participants rated their fatigue level as “extreme” on the Samn-Perelli Fatigue Scale.

#### ***Contribution of stress to error***

Stress was found to be associated with 6 of the 8 incidents investigated; this was indicated by a rating of 3 or higher on the stress measure. Stress was found to be associated with incidents of moderate harm, small harm, and near misses involving drug treatment errors, airway management error, anaesthesia machine error, and monitoring device error. In half of these incidents participants reported experiencing high amounts of anxiety, and in one incident, problems concentrating from the cognitive interference scale were found. In four of these six incidents stress was rated at the highest level.

#### ***Contribution of equipment design to error***

Equipment was found to be associated with 3 incidents; these included monitoring devices (of blood pressure, and the blood pressure cuff) and the anaesthesia machine. Monitoring devices were found to be associated with an incident of moderate severity, which occurred due to the anaesthetist failing to

perform a check. This participant noted a usability problem which contributed to error, primarily that their monitoring device did not produce an alarm like others, or as they would have expected it to.

The anaesthesia machine was associated with 2 incidents, both resulting in near misses. A usability problem was found for an incident involving the failure to perform a check on the CO<sub>2</sub> absorber being replaced, the problem cited was that the anaesthesia machine performed a self-check which allowed a pass despite a missing CO<sub>2</sub> absorber. This problem was unexpected by the participant as they said “the fact that our machines will pass a circuit leak test without a CO<sub>2</sub> absorber in the system has surprised many of my colleagues. These are new machines and are completely automated in terms of system checks. Therefore you assume that the whole system is function[al] if it passes its own check”. They also noted that the machine they used was “quite different from the ones we used previously and [that] the anaesthetists and technicians have had to learn and adjust a lot”. The other incident involving the anaesthesia machine was of an error related to controls; this was due to a failure in memory regarding the requirement to confirm actions with the machine. No system usability scores indicated additional usability problems with any equipment.

## **Discussion**

The purpose of stage 2 was to collect information on the incidence and sources of human error in anaesthesia. This analysis found that incidents involving human error are often of no harm (near misses), rarely occur, and usually occur during induction and maintenance. Incidents were found to be primarily related to

drug treatment errors and errors involving blood pressure management. Slips were suggested to be the primary cause for error, encompassing the worst and most minor of incidents observed. Fatigue and stress were found to be associated with most incidents, both being reported at high or “at risk levels” in nearly half of the incidents. Equipment design was found to contribute to a small amount of incident, and usability problems were suggested to contribute to errors involving monitoring devices. This analysis also found that other latent risks, such as personnel trade off factors and label design, could be contributing to incidents in anaesthesia. The next chapter provides a general discussion of this investigation by reviewing, findings related to this investigations research questions and the literature on human error in anaesthesia.

## **Chapter 4: General Discussion**

The purpose of this two stage investigation was to answer the research questions proposed earlier regarding the latent risks in critical incidents in anaesthesia involving human error. This section provides an overview of the findings of this investigation in relation to research and literature on human error in anaesthesia and the latent risks within it. In addition it also contains implications for anaesthesia, the limitations of this investigation, and areas of needed future research.

### **Findings in relation to research questions**

The purpose of this investigation was to assess a variety of research questions, these questions were: When does human error in anaesthesia occur, how frequent are these errors? Of what severity are they? And were they in part due to fatigue, stress, or equipment design latent failures? This investigation was able to find in general that human error in incident usually occurs between once a month and once per 3 months, usually during induction or maintenance, is often of no harm, and around half of incident is associated with fatigue and stress, and a small portion of cases are in part due to equipment design or usability problems.

### **Findings in relation to current literature**

The results of this investigation suggest that human error occurs in primarily induction and maintenance, this finding is similar to other research which has found both stages of anaesthesia to account for a total of nearly 70% of incident (Gupta et al., 2009; Staender et al., 1997). This investigation also found that drug treatment, ventilation and breathing errors, and anaesthesia machine errors occurred prior to

induction, this finding has not been found commonly in other research (Fletcher et al., 2000; Gupta et al., 2009; Staender et al., 1997; Staender, Kaufmann & Scheidegger, 2000).

Drug treatment error was found to occur before and during induction equally, a finding very different to most other research which has found induction to account for a higher proportion of drug treatment error than maintenance (Fasting & Gisvold, 2000). Drug treatment error was found to be caused by distraction due to conversation during operation, this finding is similar to other research which has found distraction to cause between 19-35% of drug treatment errors (Abeysekera et al., 2005). Label design or personnel switches due to shift changes were also suggested to cause drug treatment incident. The issue of unclear labels and their design has been discussed in previous literature and research (Fasting & Gisvold, 2000; Merry, Webster & Mathew, 2001; Webster et al., 2001), however the issue of personnel shifts in relation to drug treatment amongst anaesthetists has not received much attention and perhaps should receive more.

Ventilation and breathing management error was found to be in part due to equipment design and trade off factors, primarily the lack of a standard alarm which could alert anaesthetists to the absence of the CO<sub>2</sub> absorber, these causes of error have been found in only a few earlier critical incident studies (Cooper et al., 1984). Airway management error was found to contribute to incident due to a premature extubation, which had potential to be of high severity, and occurred within a

paediatric setting, these findings are similar to other research (Dhillon, 2003; Hove et al., 2007; Marcus, 2006).

Anaesthesia machine error was found to be due to a lapse regarding the requirement to confirm changes; this error has not been found in other research. Anaesthesia machine error was found to be unintentional and rare, this is similar to other research; for example Fasting and Gisvold (2002) found anaesthetists accidentally turning off their anaesthesia machine to explain 2.5% of human errors related to incident.

Incidents were found to occur at a very low rate, while this study used a less accurate measure than those used in critical incident monitoring studies, results suggest a similar effect to other research (Kawashima et al., 2003; Yamamoto et al., 2008). Severity of incident was found to be primarily of no harm, this is encouraging and similar to recent research (Aitkenhead, 2005; Gupta et al., 2009; Kawashima et al., 2003; Patel & Cohen, 2008; Yamamoto et al., 2008).

Fatigue was found to be associated with half of the incidents observed, this finding is somewhat similar to other research as fatigue has often been found to be one of the top contributing factors of error (Abeysekera et al., 2005; Buckley et al., 1997), however it differs, in that research often has found fatigue to contribute to a much smaller proportion of error (5-11%) than what was found in this investigation. The finding that fatigue was associated with half of the observed incidents, and that most incidents were of slips, also provides some supporting empirical evidence for

some of the theoretical work on the relationship between fatigue and slips (Durmer & Dinges, 2005).

Stress was found to be associated with half of the incidents observed, this is in contrast to other research which estimates it to contribute to 10.44-12% of errors in anaesthesia (Buckley et al., 1997; Merry et al., 2001; Webster et al., 2010). The results of stress also differ from previous research in that high amounts of anxiety and troubles concentrating were found during incident. These findings add further support to theories of stress which propose that stress leads to inefficiency in mental processing and increase the chance for error (Derakshan & Eysenck, 2009).

Equipment design and usability problems in this investigation were found to contribute to a small amount of error, specifically with monitoring devices and the controls of the anaesthesia machine, all of these findings have been found in other research (Arnstein, 1997; Cooper et al., 1984; Fasting & Gisvold, 2002; Weinger, 1999; Weinger & Slagle, 2002).

### **Implications**

The results of this investigation have various implications for anaesthesia. Fatigue was found to be a major contributor of error, therefore following best recommended practice such as ensuring a safe workload is established and adhered to could possibly reduce error, safe workload has been recommended as being determined by having a safe ratio of trained anaesthetists to patients at any time (Merry, Cooper, Soyannwo, Wilson & Eichhorn, 2010). Policies should ensure that anaesthetists communicate all relevant information, such as patient information as

well as the tasks they need to currently perform at the time of shift change, such as the replacing of a CO<sub>2</sub> absorber, this has also been similarly suggested as recommended practice (Merry et al., 2010). Training should perhaps focus additionally more on teaching skills for operating under high anxiety and high stress. And, organizations should ensure there is an adequacy of alarms when selecting equipment and training for anaesthetists to ensure that they are aware of absences of “standard” or previously used features in new equipment as this should reduce the chance for equipment design related errors.

### **Summary**

In this investigation the frequency, severity, stage of anaesthesia, and the latent risks of fatigue, stress, and equipment design were investigated to provide an understanding of modern incidents in anaesthesia and their potential causes. This investigation found that human error is infrequent, often of no harm, and usually occurs during induction and maintenance. Drug treatment errors and airway management errors were found to be highly represented amongst error, and error was found to be due mostly to slips. Fatigue and stress were found to be at high levels in half of the incidents observed; they could possibly explain a high proportion of errors (slips) observed, this finding differed the most in comparison to all of the other findings of this investigation. And, equipment design was found to only be associated with a small amount of incident.

## **Limitations**

In this investigation there is a variety of limitations that need to be considered when interpreting the findings of this study. The first limitation was that a very small sample was used; therefore generalization of the results of this study is cautioned. There was a high amount of missing data (61.5% completion rate), this may have been due to the use of a large amount of questions (43) and the fact that anaesthetists belong to a profession with a high amount of working hours per week. Another limitation was that it was impossible to control whether or not anaesthetists were in fact participating as invitations to participate were sent by the participant's respective district health board, not the researcher, in this regard however no incident report was found that would have indicated a different professional group might have participated. The questionnaire for this investigation used some measures or questions that were not standardized, this was because of a lack of availability of standardized measures and the absence of short measures as long measures would have made full participation less likely and more difficult. And lastly, this investigation relied upon self-report and retrospective research methods therefore incidents reported cannot be verified.

## **Future Research**

The results of this study suggest that, similarly to other research, errors occur most during induction and maintenance, therefore research into these processes, such as what latent risks are most influential during these processes, will likely maximize the utility of future research. Future research is needed to clarify the role human error has in mortality and morbidity rates in anaesthesia as little was found during this

investigation or in literature. Drug treatment errors that occur due to mistakes are still currently an area of future needed research as most drug treatment errors appear to be slips and the main focus of research. Usability assessment in anaesthesia machines is also another area of future needed research; this could potentially lead to safer designs. Future research is needed regarding how fatigue and stress contribute to incidents of harm in anaesthesia due to this investigation analysing almost exclusively “near miss” incidents, additionally how these can be reduced in anaesthesia is another good venue for future research. And finally, the development of standardized measures for fatigue, stress, and possibly other latent failures in critical incidents could be of potential benefit to researchers as it would allow easier comparisons between studies and could increase the chance of these measures being included for studying human error.

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## APPENDIX A

### Critical Incident Technique Questions

#### Question set 1)

Tell me about a time when a patient was almost harmed...

What was the procedure and tasks performed?

In your opinion what lead up to the problem?

What equipment was used when this happened? Can you remember how it was being used?

Has this problem occurred since then?

How frequent is this problem?

What rating would you use to describe that event?

#### Question set 2)

Tell me about a time when a patient was harmed...

What was the procedure and tasks performed?

In your opinion what lead up to the problem?

What equipment was used when this happened? Can you remember how it was being used?

Has this problem occurred since then?

How frequent is this problem?

What rating would you use to describe that event?

#### Question set 3)

Tell me about a time when you experienced a mechanical failure...

What was the procedure and tasks performed?

In your opinion what lead up to the problem?

What equipment was used when this happened? Can you remember how it was being used?

Has this problem occurred since then?

How frequent is this problem?

What rating would you use to describe that event?

## APPENDIX B

### Ratings of severity

Level of Severity	Description
Low	Momentary difficulty or confusion however does not prevent users from accomplishing their task. Described as temporary difficulty. ( I just had to figure X out, and it wasn't hard to do that.)
Medium	High amount of difficulty, confusion however does not prevent users from accomplishing their task. (I just had to figure X out, which was very hard to do, it took a lot of time or effort).
High	I could not, or don't see how anyone else could complete the intended task. OR problems associated with a fatal outcome

Criteria from Fasting and Gisvold's "Equipment problems during anaesthesia" (2002)

## APPENDX C

### Human Factors in Anesthesia Survey

This survey covers topics related to social support, chronic stress, fatigue and stress, usability and critical incidents in the workplace. This survey includes both multiple choice and open ended questions. Please take your time and do not rush. In this survey you can go backwards and change answers at any time. This survey is intended for anesthetists and estimated to take 15 minutes.

Remember your answers will be kept confidential, your anonymity is protected and you may withdraw from participation at any time.

Q1 My experience level is...

- Current trainee
- Registered with under 1 year of experience
- Registered with under 3 years of experience
- Registered beyond 3 years of experience

Using the response scale below, please indicate how often your colleagues provide you with each of the following in the past three months. (Note to reviewer: Q2-Q5 are items from the social support scale)

Q2 Helpful information or advice

- Never
- Very occasionally
- Sometimes
- Often
- Very often
- All the time

Q3 Sympathetic and understanding advice

- Never
- Very occasionally
- Sometimes
- Often
- Very often
- All the time

Q4 Clear and helpful feedback

- Never
- Very occasionally
- Sometimes
- Often
- Very often
- All the time

Q5 Practical assistance

- Never
- Very occasionally
- Sometimes
- Often
- Very often
- All the time

The next questions ask about your feelings and thoughts during THE PAST MONTH. In each question, you will be asked HOW OFTEN you felt or thought a certain way. Although some of the questions are similar, there are small differences between them and you should treat each one as a separate question. The best approach is to answer fairly quickly. That is, do not try to count up the exact number of times you felt a particular way, but tell me the answer that in general seems the best. For each statement, please tell me if you have had these thoughts or feelings: never, almost never, sometimes, fairly often, or very often (Read all answer choices each time). (Note to reviewer: Q6-Q15 are items from the perceived stress scale)

Q6 In the last month, how often have you been upset because of something that happened unexpectedly?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q7 In the last month, how often have you felt that you were unable to control the important things in your life?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q8 In the last month, how often have you felt nervous and “stressed”?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q9 In the last month, how often have you felt confident about your ability to handle your personal problems?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q10 In the last month, how often have you felt that things were going your way?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q11 In the last month, how often have you found that you could not cope with all the things that you had to do?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q12 In the last month, how often have you been able to control irritations in your life?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q13 In the last month, how often have you felt that you were on top of things?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q14 In the last month, how often have you been angered because of things that were outside of your control?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q15 In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Q16 What times or tasks would you say there is a lack of stimulation you might characterize as boredom? (Open ended question)

Example: I find charting a particularly boring activity because often I am monitoring something with little change for long periods of time.

Q17 What times or tasks do you have to apply a very high amount of concentration and effort? (Open ended question)

Example: I find estimating the end of surgery and the beginning of recovery/reversal to require a high amount of effort because it requires monitoring, estimating, and adjusting various drugs carefully.

Q18 At What times or tasks would you say on the job you experience stress? (Open ended question)

Example: I feel stressed when we have to assist with certain types of procedures or patients because in the past they are more difficult to manage safely.

Q19 In what way do you cope with stress? (Open ended question)

Example: My stress regarding my ongoing education is relieved by the support I get from my colleagues.

The following questions relate to instances of critical incidents in anesthesia. The following questions include both multiple choice and open ended questions. Please provide as much detail as possible; please try to choose incidents that were of high severity or frequency. Remember you can view and edit previous pages and save and continue at any time. Remember any information you give will be kept anonymous.

Q20 When during the anesthetic process did this incident occur?

- Pre-induction
- During induction
- Beginning of procedure
- Middle of procedure
- End of procedure
- After procedure (still in Operating Room)

Q21 What was the error and what would you say contributed or caused it? (Open ended question)

Q22 Was any equipment associated with the error and negative outcome?

- Drug administration equipment
- Anesthesia machine
- Breathing circuit
- Ventilator
- Fluid management
- I.V apparatus
- Monitoring device
- Other
- Equipment not associated with error

With that equipment in mind please answer the following questions. (Note to reviewer: Q23-Q32 are items from the system usability scale)

Q23 I think that I would like to use this system frequently

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q24 I found the system unnecessarily complex

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q25 I thought the system was easy to use

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q26 I think that I would need the support of a technical person to be able to use this system

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q27 I found the various functions in this system were well integrated

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q28 I thought there was too much inconsistency in this system

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q29 I would imagine that most people would learn to use this system very quickly

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q30 I found the system very cumbersome to use.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q31 I felt very confident using the system

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q32 I needed to learn a lot of things before I could get going with this system

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Q33 What would you say are the most important usability problems you encountered with this or other equipment, if any? (Open ended question)

Q34 Please rate the level of fatigue you experienced during the incident. (Note to reviewer: this item is from Samn-Perelli's fatigue scale)

- Fully Alert
- Very Lively
- Okay
- A Little Tired
- Moderately Tired
- Extremely Tired
- Completely Exhausted

Q35 Please rate the level of stress you experienced during the incident.

Please rate the level of stress you experienced during the incident.

0	1	2	3	4	5
Stress					

The presented scale is shown to participants with 6 possible choices (0-5).

Q36 During the incident did you experience any of the following problems?

- High amounts of anxiety
- Trouble concentrating
- Having to avoid certain thoughts
- Attempting to put problems out of your mind
- Thinking about something you did not mean to
- Unwanted ideas continuously entering your mind
- None of the above

Q37 How frequently does this incident occur?

- Very common (I might see this incident weekly)
- Common (I might see this incident within 2 weeks or less)
- Uncommon (I might see this incident only once a month)
- Rare (I might see this incident once per every 2 or 3 months)
- Almost never (Incredibly rare, only seen once or a few times within lifetime)

Q38 How severe would you rate this incident?

- No harm done
- Near miss
- Small amount of harm
- Moderate amount of harm
- Severe or fatal amount of harm

Q39 Does this incident still occur?

- Yes
- No

Q40 Is there another incident you would like to report now? If you can think of a second incident please answer "yes" and you will be asked an additional 20 short questions about it.

- Yes
- No

If No Is Selected, Then Participants skip to end of survey. If Yes is Selected, Then Participants are presented a copy of questions 20-39.

End of Survey Text
Thank you for completing this survey. If you would like a summary of results of this study emailed to you please email the researcher @ tedbelbin@gmail.com.

## APPENDIX D

### Recruitment material

Title: Participants wanted for research into anaesthesia procedures and equipment

To the department manager of anaesthesia

My name is Ted Belbin, I am a masters student at the University of Waikato majoring in organizational psychology, undertaking a thesis looking at stress, fatigue and usability issues and their role in critical incidents, within anaesthesia. I am currently looking for 41 anaesthetists to complete a 15 minute online survey. Participation is open to any type of anaesthetist, including trainees. Participants are guaranteed anonymity and confidentiality, meaning no identifying characteristics is used during the survey or may be used during analysis and only I and my supervisors may review any information participants provide. The outcomes of this study will include quantitative and qualitative information on the risk factors in critical incidents.

If you are able to participate, send this message in addition to the link at the bottom of this email to prospective participants.

This study has been approved by the University of Waikato's School of Psychology's Ethics Committee. If you have any questions please feel free to contact me: Ted Belbin at tedbelbin@gmail.com my supervisors for this research are A/Prof Samuel Charlton (samiam@waikato.ac.nz) and Dr Maree Roche (mroche@waikato.ac.nz). If you have any concerns about this research you may contact the Convener of Research and Ethics Committee, A/Prof John Perrone (jpnz@waikato.ac.nz).

Thank you,

Ted Belbin.

Link to survey:

<http://psychology.waikato.ac.nz/anaesthesia.html>

## APPENDIX E

### Participant information sheet



THE UNIVERSITY OF  
**WAIKATO**  
*Te Whare Wānanga o Waikato*

I am conducting research into anesthesia procedures and equipment in New Zealand. This research is part of my Masters Thesis in Organizational Psychology at the University of Waikato investigating a variety of human factors within anesthesia that have been highlighted in previous research as increasing the chances of unsafe actions and incidents. These factors are stress, fatigue, and usability issues with equipment.

Your participation is important. Results of this study may help health researchers and organizations better understand how to reduce error, improve equipment design and help improve your work environment.

Most questions in this survey are multi-choice, while some are open ended questions. This survey will take approximately 15 minutes. You can save your answers and continue the survey at a later time if you wish.

In this study participants are guaranteed the following rights: (1) The right to anonymity, meaning no information identifying the participant may be used in this research. (2) The right to confidentiality, meaning only myself and my supervisors can view information you provide and, (3) participants can receive a summary of the results of this study upon request.

This study has been approved by the University of Waikato's School of Psychology's Ethics Committee.

By clicking the link below you agree you have read the information above and consent to the terms of this study.

**Begin survey**

If you have any questions or request a summary of results of this study please feel free to contact me: Ted Belbin at [tedbelbin@gmail.com](mailto:tedbelbin@gmail.com)  
My supervisors for this research are A/Prof Samuel Charlton ([samiam@waikato.ac.nz](mailto:samiam@waikato.ac.nz)) and Dr Maree Roche ([mroche@waikato.ac.nz](mailto:mroche@waikato.ac.nz)): If you have any concerns about this research you may contact the Convener of the Research and Ethics Committee, A/Prof John Perrone ([jpnz@waikato.ac.nz](mailto:jpnz@waikato.ac.nz)).