The Illusion of Perfection: Why Safe Anaesthesia Depends on Resilient Systems, Not Perfect Clinicians

Abstract

Anaesthesia is recognised as one of healthcare's greatest patient safety achievements. Advances in monitoring, pharmacology, equipment design and professional education have substantially reduced anaesthesia-related morbidity and mortality[1]. Despite these advances, adverse events and near misses continue to occur and frequently involve highly skilled clinicians[2].

Anaesthesia is a complex sociotechnical environment that requires continuous surveillance, rapid decision-making and coordinated team performance. Human performance is influenced by cognitive workload, communication, fatigue, environmental conditions, technology and organisational factors, creating circumstances in which error remains an inherent possibility[3].

Human factors science provides a framework for understanding these vulnerabilities and for designing systems that support safe performance. Rather than focusing solely on individual actions, a systems perspective recognises that patient safety emerges from interactions between people, tasks, technologies and organisations[4].

This paper examines human factors principles relevant to anaesthesia, including cognitive overload, interruptions, alarm fatigue, communication failures and situational awareness. It explores how high-reliability principles, resilience engineering and psychologically safe team cultures strengthen patient safety[5]. Particular emphasis is placed on the role of Anaesthetic Technicians as independent safety barriers, cognitive partners and contributors to system resilience through equipment management, monitoring, troubleshooting, verification processes and crisis response[6].

Safe anaesthesia is not achieved because clinicians are incapable of error. It is achieved because resilient teams and systems recognise human limitations and are deliberately designed to anticipate, detect and recover from error[7].

Keywords: Human factors; anaesthesia; patient safety; resilience engineering; high-reliability organisations; cognitive workload; situational awareness; crisis resource management; Anaesthetic Technicians; systems resilience.

The Illusion of Perfect Performance

Most anaesthetics proceed without serious complication, but their apparent smoothness can conceal the continuous work required to keep patients safe. Throughout each case, anaesthesia professionals anticipate physiological change, detect subtle deviations, adjust treatment and equipment, and resolve developing problems before they progress to harm[8].

This remarkable safety record can create an implicit expectation that patient harm is preventable through sufficient expertise, vigilance and technical proficiency. Anaesthetists, Anaesthetic Technicians and anaesthetic nurses are frequently perceived as the final barrier between patients and harm, operating within a specialty where precision and reliability are assumed rather than simply desired.

However, this expectation of flawless performance represents an illusion.

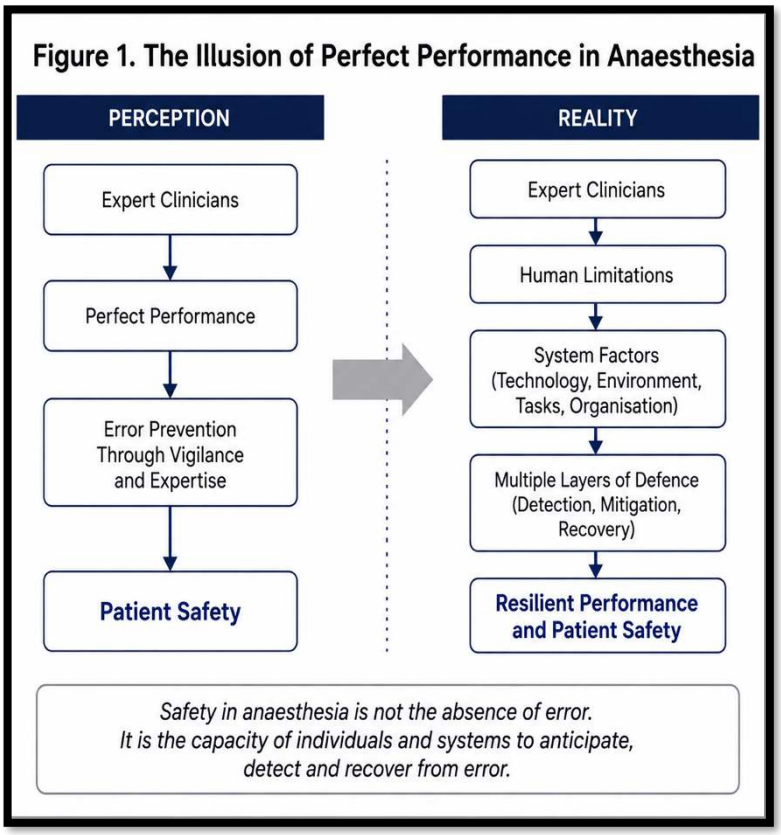
Despite substantial improvements in patient safety, adverse events and near misses continue to occur within anaesthesia practice. Importantly, these incidents frequently involve highly experienced clinicians possessing considerable knowledge, technical expertise and a strong commitment to patient safety. Investigations

[1] Cooper et al., 2002; Haller et al., 2011; Merry & Cooper, 2018
[2] Kohn et al., 2000; Reason, 2000
[3] Flin et al., 2008; Young et al., 2015; Carayon et al., 2014
[4] International Ergonomics Association, 2020; Carayon et al., 2014; Reason, 2000
[5] Endsley, 1995; Grundgeiger & Sanderson, 2009; Sendelbach & Funk, 2013; Edmondson, 2019; Hollnagel, 2018; Weick & Sutcliffe, 2015
[6] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[7] Hollnagel et al., 2015; Wears et al., 2015; Weick & Sutcliffe, 2015
[8] Cooper et al., 2002; Haller et al., 2011; Merry & Cooper, 2018

consistently demonstrate that such events rarely arise from incompetence or negligence alone. Instead, they emerge from interactions between human cognition, technology, environmental conditions, communication processes and organisational systems[9].

Anaesthesia is a dynamic sociotechnical environment requiring continuous surveillance, rapid decision-making and coordinated team performance. Clinicians must simultaneously interpret physiological information, administer potent medications, anticipate patient responses, communicate effectively with multidisciplinary teams and adapt to rapidly evolving situations. During a rapid-sequence induction, for example, an anaesthetist may administer multiple induction agents, supervise airway interventions, monitor haemodynamic changes, interpret oxygen saturation trends and formulate contingency plans for failed intubation within a matter of minutes. These competing demands create conditions in which error remains an inherent possibility, regardless of experience or expertise[10].

Human factors science offers an alternative perspective on patient safety. Rather than asking who failed, human factors seeks to understand why actions and decisions made sense within the circumstances in which they occurred and how systems can be designed to support safe performance despite inevitable human limitations. This perspective recognises that human cognition is finite and that performance is continually shaped by workload, environmental conditions, technology, organisational structures and team interactions[11].



High-risk industries such as commercial aviation and nuclear power have long recognised that expecting perfect human performance is unrealistic and potentially hazardous. Their exceptional safety records have been achieved not by eliminating human error, but by developing systems that anticipate vulnerability, detect emerging problems and support recovery before harm occurs[12].

Anaesthesia has increasingly embraced similar principles. The introduction of standardised monitoring, crisis resource management, simulation training, checklists and multidisciplinary safety initiatives reflects a growing understanding that patient safety is fundamentally a systems issue rather than solely a matter of individual competence[13].

Safe anaesthesia is therefore best understood not as the absence of error, but as the capacity of clinicians and systems to recognise vulnerabilities, adapt to changing circumstances and recover from developing problems before patient harm occurs. These adaptive capacities emerge through resilient multidisciplinary teams in which anaesthetists, Anaesthetic Technicians and nursing staff collectively monitor, anticipate and respond to evolving clinical situations. Within these systems, Anaesthetic Technicians contribute through equipment readiness, continuous observation, troubleshooting expertise and crisis support, strengthening system resilience and providing additional layers of defence against patient harm[14].

Human Factors and the Reality of Clinical Performance

[9] Kohn et al., 2000; Reason, 2000; Catchpole et al., 2008
[10] Gaba, 2000; Flin et al., 2008; Fletcher et al., 2003
[11] International Ergonomics Association, 2020; Carayon et al., 2014; Reason, 2000; Young et al., 2015
[12] Helmreich & Merritt, 2000; Weick & Sutcliffe, 2015
[13] Gaba, 2000; Arriaga et al., 2013; Hollnagel et al., 2015
[14] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Hollnagel et al., 2015; Wears et al., 2015

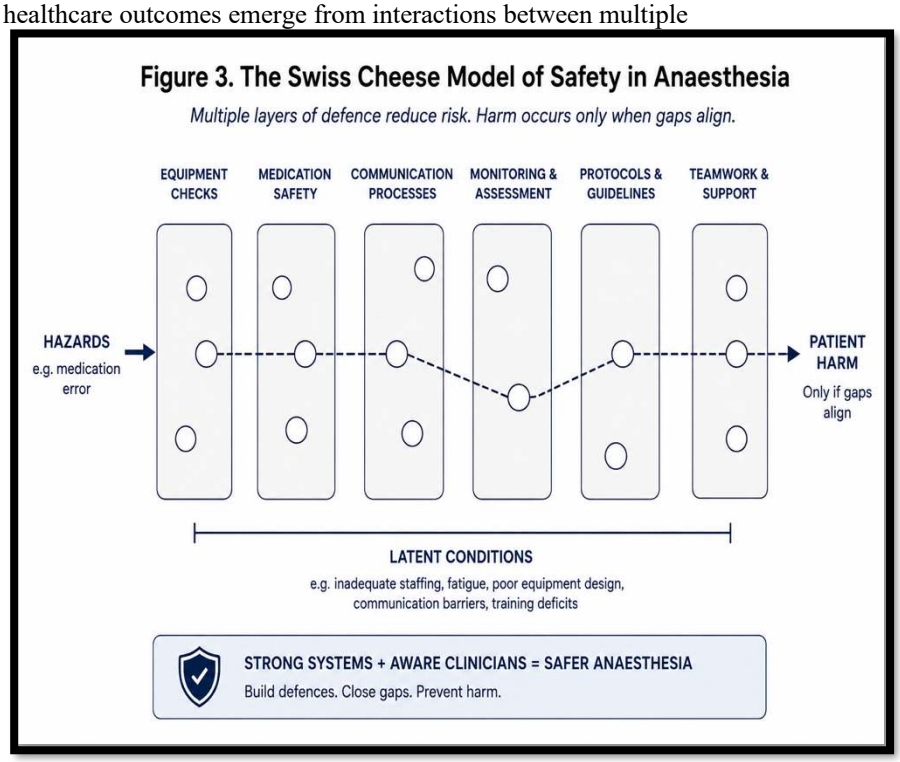
Human factors is the scientific discipline concerned with understanding the interactions between people, technologies, tasks and organisational systems. Drawing upon principles from psychology, ergonomics, engineering and organisational science, human factors seeks to optimise both human performance and patient safety. Although the discipline has gained increasing prominence within healthcare over recent decades, its principles have long been embedded within high-risk industries such as commercial aviation, nuclear power and military operations, where safety depends upon understanding and supporting human performance under conditions of complexity and uncertainty[15].

These industries recognise a fundamental reality: even highly skilled professionals remain vulnerable to the limitations of human cognition. Human performance is not determined solely by knowledge and technical competence. Rather, it is continually shaped by workload, environmental conditions, equipment design, communication processes and organisational factors. Consequently, safety is achieved not by expecting flawless performance, but by designing systems that recognise human limitations and support effective decision-making[16].

Anaesthesia shares many characteristics with these high-hazard industries. It is a dynamic, high-consequence specialty that requires continuous surveillance, rapid decision-making and effective teamwork while managing sophisticated technologies and significant physiological risk. Anaesthesia professionals must simultaneously assess patients, administer potent medications, interpret physiological trends, anticipate complications and communicate effectively with multidisciplinary teams. Performance therefore depends not only on individual expertise, but also on the systems within which clinicians work[17].

Historically, healthcare often approached patient safety from a person-centred perspective, seeking to identify who made a mistake and how individual behaviour contributed to adverse outcomes. Although accountability remains important, this approach risks overlooking the broader conditions that influence performance. Human factors instead adopts a systems perspective, asking why actions and decisions made sense within the circumstances in which they occurred and what factors shaped those decisions[18].

A systems approach recognises that healthcare outcomes emerge from interactions between multiple components, including people, technologies, processes, environments and organisational structures. From this perspective, clinicians are rarely the primary cause of accidents. More commonly, they inherit system vulnerabilities that have accumulated over time and become visible only when conditions align[19].



One of the most influential models of systems thinking is James Reason's Swiss Cheese Model of organisational accidents. The model proposes that safety systems contain multiple layers of defence designed to prevent hazards from reaching patients. These defences include monitoring technologies, equipment checks, medication protocols, communication processes and organisational policies. However, each layer contains weaknesses or "holes". Some vulnerabilities are active failures, such as

[15] International Ergonomics Association, 2020; Carayon et al., 2014; Helmreich & Merritt, 2000
[16] Helmreich & Merritt, 2000; Flin et al., 2008; Young et al., 2015
[17] Gaba, 2000; Flin et al., 2008; Fletcher et al., 2003
[18] Reason, 2000; Kohn et al., 2000
[19] Carayon et al., 2014; Reason, 2000

selecting the wrong medication, while others are latent conditions that remain hidden until circumstances align, including inadequate staffing, interruptions, poorly designed equipment or communication barriers[20].

The relevance of this model to anaesthesia is readily apparent. Consider an accidental medication administration error. Such an event rarely arises because a clinician simply selected the wrong syringe. Contributing factors may include similar ampoule packaging, interruptions during medication preparation, poor lighting, excessive workload, fatigue or inadequate checking procedures. Viewed through a human factors lens, the error becomes the consequence of multiple interacting vulnerabilities rather than the isolated action of a single individual[21].

Human cognition itself possesses inherent limitations that become increasingly evident within complex environments such as anaesthesia. Attention is selective and finite, meaning that concentrating on one task inevitably reduces awareness of other information. Working memory can process only a limited amount of information at any given time and becomes vulnerable when demands exceed available cognitive resources. Decision-making is similarly constrained by time pressure, uncertainty and incomplete information[22].

These limitations are particularly relevant in anaesthesia because clinicians frequently operate at the limits of human information-processing capability. During induction of anaesthesia, for example, an anaesthetist may simultaneously administer medications, monitor cardiovascular responses, supervise airway interventions, communicate with theatre staff and formulate contingency plans should complications arise. During an unexpected difficult airway, cognitive demands escalate further as clinicians rapidly reassess information, reprioritise actions and coordinate team responses. Under these circumstances, human performance cannot be understood solely by considering individual knowledge or technical skill; it must also be understood in relation to cognitive workload and system demands[23].

Human factors also emphasises the influence of technology and environmental design on performance. Advances in monitoring and automation have undoubtedly improved patient safety, yet technology can also introduce new complexities and unintended consequences. Poorly designed interfaces, excessive alarms, inconsistent equipment layouts and look-alike medication packaging may increase cognitive workload and contribute to error. Similarly, environmental factors including noise, interruptions, temperature and workspace organisation influence attention, communication and decision-making[24].

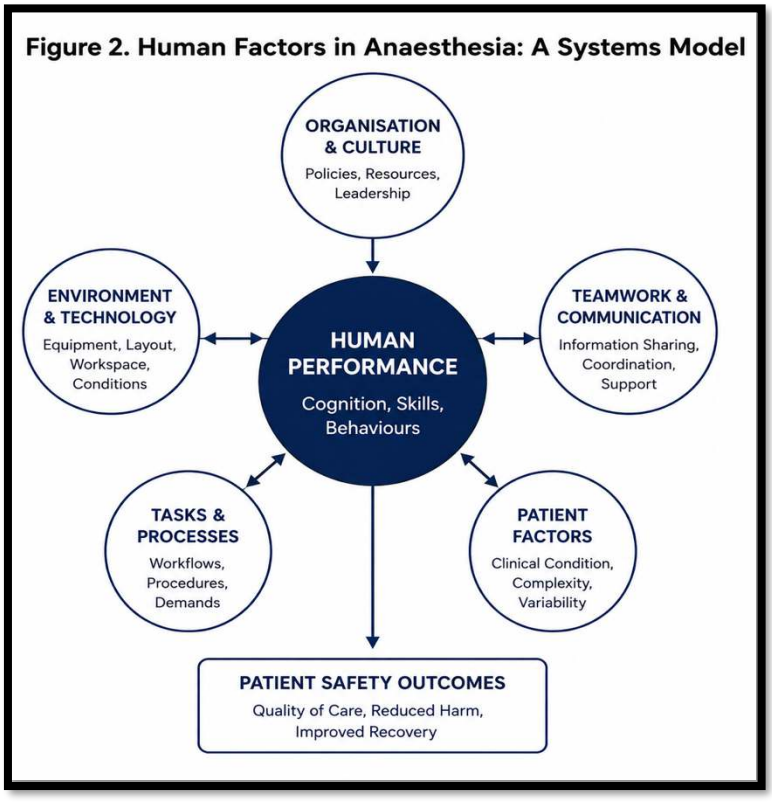


Figure 2. Human Factors in Anaesthesia: A Systems Model

Importantly, human factors does not seek to eliminate human involvement from healthcare systems. Humans possess capabilities that technology cannot easily replicate, including adaptability, intuition, creativity and the ability to respond effectively to unexpected situations. In many cases, patient safety is preserved precisely because clinicians identify developing problems, adapt to changing circumstances and recover from situations before harm occurs[25].

This understanding has contributed to a shift in contemporary patient safety thinking. Traditional approaches, often referred to as Safety-I, focus on understanding why things go wrong and preventing recurrence. In

[20] Reason, 2000
[21] Catchpole et al., 2008; Reason, 2000
[22] Flin et al., 2008; Young et al., 2015; Croskerry, 2003
[23] Gaba, 2000; Flin et al., 2008; Fletcher et al., 2003
[24] Carayon et al., 2014; Catchpole et al., 2008; Sendelbach & Funk, 2013; Grundgeiger & Sanderson, 2009
[25] Hollnagel et al., 2015; Wears et al., 2015

contrast, Safety-II seeks to understand why things usually go right despite complexity, uncertainty and continual exposure to hazards. From a Safety-II perspective, clinicians continuously adapt their behaviour to meet changing demands, and these adaptive capacities are fundamental to maintaining safe care[26].

Within these systems, Anaesthetic Technicians contribute to resilience through equipment readiness, independent observation, troubleshooting expertise and crisis support, functioning as additional layers of defence against patient harm[27].

Within anaesthesia, human factors therefore provides a framework not only for understanding error, but also for understanding successful performance and system resilience. It encourages a shift away from individual blame and towards a deeper appreciation of the interactions between people, technologies, tasks and organisations. By recognising human limitations, optimising system design and supporting adaptive performance, human factors principles provide valuable strategies for strengthening resilience and enhancing patient safety within increasingly complex perioperative environments[28].

~~***Why Errors Still Occur in Safe Anaesthesia***~~

Anaesthesia is characterised by an apparent paradox. It remains one of healthcare's safest specialties while simultaneously operating under conditions that are highly vulnerable to human error. Anaesthesia professionals routinely manage potent medications, rapidly changing physiology, sophisticated technologies and time-critical emergencies while maintaining exceptionally high standards of patient care[29].

This vulnerability does not reflect deficiencies in professional standards or clinical competence. Rather, it reflects the reality that humans possess finite cognitive resources and must continually adapt to environments characterised by uncertainty, competing priorities and significant consequences of failure[30].

Cognitive Workload and Information Processing:

Perhaps the most significant contributor to vulnerability in anaesthesia is cognitive workload. Cognitive workload refers to the mental effort required to process information, make decisions and perform tasks. Anaesthesia professionals continually engage in complex cognitive activities, including patient assessment, physiological interpretation, pharmacological calculations, procedural planning and anticipation of potential complications[31].

Unlike many healthcare environments, anaesthesia demands continuous vigilance. Clinicians must monitor multiple physiological parameters while simultaneously anticipating future events and preparing interventions before patient deterioration occurs.

For example, during an emergency Caesarean section under general anaesthesia, clinicians may simultaneously perform rapid-sequence induction, manage airway instrumentation, monitor maternal physiology, prepare for neonatal resuscitation and coordinate communication with surgical and midwifery teams. These competing demands place considerable strain on human cognitive systems.

Human cognitive resources are finite. Excessive cognitive workload can result in delayed decision-making, reduced situational awareness, missed information and increased susceptibility to error. Importantly, cognitive overload can affect even highly experienced clinicians because expertise does not eliminate the fundamental limitations of human cognition[32].

Time Pressure and Decision-Making Under Uncertainty:

Anaesthesia frequently requires clinicians to make decisions under considerable time pressure. Many critical incidents evolve rapidly, leaving little opportunity for deliberate reflection or consultation. Situations such as

[26] Hollnagel, 2018; Hollnagel et al., 2015
[27] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[28] Carayon et al., 2014; Hollnagel et al., 2015; Weick & Sutcliffe, 2015
[29] Merry & Cooper, 2018; Haller et al., 2011
[30] Reason, 2000; Flin et al., 2008
[31] Young et al., 2015; Flin et al., 2008
[32] Young et al., 2015; Flin et al., 2008

airway obstruction, severe haemorrhage, anaphylaxis, malignant hyperthermia or cardiovascular collapse demand immediate recognition and intervention.

Under these circumstances, clinicians often rely on pattern recognition and mental shortcuts, commonly referred to as heuristics. These cognitive strategies allow efficient decision-making and are generally highly effective. However, they may also increase vulnerability to error when clinical situations do not conform to expected patterns[33].

Time pressure can also promote anchoring, whereby an initial explanation continues to guide management despite new or contradictory information. As attention narrows around the presumed cause, alternative diagnoses may receive less consideration and opportunities for earlier recognition may be missed.

Clinical information is frequently incomplete and evolving. Anaesthesia professionals must often act before definitive diagnoses can be established, making decisions based upon limited information and rapidly changing physiological trends. This combination of uncertainty and time pressure creates conditions that challenge even highly experienced clinicians[34].

~~Interruptions and Task Switching:~~

Interruptions are common within operating theatre environments and represent a well-recognised source of error. Anaesthesia professionals are frequently interrupted by equipment alarms, requests from surgeons, telephone calls, changes in procedural requirements and communication from other team members.

Although many interruptions are clinically necessary, they require clinicians to suspend one task, redirect attention and subsequently resume the original activity. This process places demands on working memory and increases the likelihood of forgetting information or omitting critical steps[35].

Medication preparation is particularly vulnerable to interruption-related errors. A clinician drawing up emergency medications may be interrupted to respond to a change in patient physiology or answer a procedural question, increasing the risk of selecting an incorrect ampoule or omitting a medication entirely.

Closely related to interruptions is the challenge of multitasking. Anaesthesia professionals routinely monitor physiological variables, document information, administer medications, communicate with team members and prepare equipment concurrently. In reality, humans do not perform multiple cognitive tasks simultaneously but instead rapidly switch attention between competing activities. This task switching carries cognitive costs and increases the likelihood of errors and omissions[36].

Alarm Fatigue and Technology Dependence:

Technological advancements have transformed anaesthesia practice and significantly improved patient safety. Modern anaesthesia workstations provide sophisticated monitoring capabilities and early warning systems that facilitate prompt recognition of patient deterioration[37].

However, increasing reliance upon technology has introduced new human factors challenges.

Operating theatres contain numerous devices capable of generating alarms, many of which are transient or clinically insignificant. Frequent exposure to low-priority alarms may result in desensitisation and delayed responses[38].

[33] Croskerry, 2003; Flin et al., 2008
[34] Croskerry, 2003
[35] Grundgeiger & Sanderson, 2009
[36] Flin et al., 2008; Grundgeiger & Sanderson, 2009
[37] Merry & Cooper, 2018
[38] Sendelbach & Funk, 2013

For example, repeated nuisance pulse oximetry alarms during electrocautery may reduce responsiveness to subsequent alarms, potentially delaying recognition of circuit disconnection or significant physiological deterioration.

Technology can also foster automation bias. Clinicians may develop excessive trust in monitoring systems and assume that equipment will reliably identify developing problems. Although monitoring technologies are invaluable, they remain susceptible to malfunction, limitations in sensitivity and user-related factors. Overreliance on technology may inadvertently reduce independent verification and diminish active situational awareness[39].



Technology therefore functions as both a safe

Fatigue and Sustained Vigilance:

Fatigue represents another significant contributor to human vulnerability within anaesthesia. The specialty frequently involves prolonged periods of sustained attention, emergency responsibilities, overnight work and extended procedural lists.

Fatigue adversely affects attention, reaction time, communication, memory and decision-making abilities. Cognitive impairment associated with sleep deprivation has been compared with the effects of alcohol intoxication, with measurable reductions in psychomotor performance and executive functioning[40].

The effects of fatigue are particularly concerning because individuals often underestimate the extent of their own impairment. Clinicians experiencing fatigue frequently continue to believe they are functioning effectively despite objective reductions in performance.

This discrepancy creates an important patient safety concern within anaesthesia, where rapid recognition and response to deterioration are essential[41].

Emergencies and Escalating Complexity:

Anaesthesia is characterised by periods of relative stability punctuated by episodes of rapidly escalating complexity. A routine anaesthetic may progress uneventfully before suddenly deteriorating due to anaphylaxis, massive haemorrhage, equipment failure or airway compromise.

[39] Carayon et al., 2014; Catchpole et al., 2008
[40] Lockley et al., 2007
[41] Lockley et al., 2007; Australian and New Zealand College of Anaesthetists, 2022

These events dramatically increase cognitive workload and frequently exceed normal information-processing capacity. Stress responses may narrow attentional focus, impair working memory and reduce the ability to process peripheral information[42].

Successful management therefore depends not only upon technical competence, but also upon non-technical skills including communication, leadership, situational awareness and teamwork[43].

~~*Team Dynamics and Communication:*~~

Safe anaesthesia is fundamentally a team activity. Effective perioperative care depends upon collaboration between anaesthetists, Anaesthetic Technicians, nursing staff and surgeons.

However, team interactions are influenced by professional hierarchies, interpersonal relationships and organisational culture. Authority gradients may discourage individuals from questioning decisions, raising concerns or communicating uncertainty[44].

Conversely, psychologically safe environments encourage all team members to contribute information and challenge assumptions without fear of criticism or negative consequences[45].

An Anaesthetic Technician questioning unexpectedly low tidal volumes, an unusual capnography trace or a discrepancy in medication preparation may identify developing problems before patient harm occurs. These examples illustrate that patient safety frequently depends upon distributed observation and the willingness of all team members to communicate concerns[46].

The Safety Paradox of Anaesthesia:

The factors described above illustrate a fundamental paradox within anaesthesia. The specialty remains exceptionally safe despite operating under conditions that are inherently vulnerable to human error.

This safety record is not evidence that clinicians are immune to error. Rather, it reflects the presence of numerous system defences, adaptive behaviours and team-based strategies that enable clinicians to recognise, intercept and recover from developing problems[47].

Understanding the vulnerabilities inherent within anaesthesia is therefore not an exercise in identifying weaknesses. Rather, it is an essential step towards designing systems that better support human performance and further strengthen patient safety in increasingly complex perioperative environments[48].

The capacity to recognise and recover from emerging problems is distributed across the multidisciplinary team, with Anaesthetic Technicians contributing through equipment readiness, independent observation, troubleshooting and crisis support[49].

How Errors Develop in Anaesthesia

Errors in anaesthesia rarely arise from a single action or isolated lapse. Rather, they emerge through interactions between human cognition and the systems in which clinicians work. Understanding how these errors arise creates opportunities to strengthen system defences, improve recovery mechanisms and enhance patient safety[50].

Importantly, many errors in anaesthesia do not result in patient harm. Patient physiological reserve may provide a temporary buffer, allowing a brief disturbance to be tolerated while an emerging problem is identified and corrected. However, physiological reserve varies considerably between patients and cannot be treated as a dependable safety barrier. Emerging problems are also frequently intercepted through vigilance, teamwork,

[42] Flin et al., 2008
[43] Fletcher et al., 2003; Gaba, 2000
[44] Helmreich & Merritt, 2000
[45] Edmondson, 1999; Edmondson, 2019
[46] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[47] Hollnagel et al., 2015; Wears et al., 2015
[48] Weick & Sutcliffe, 2015; Hollnagel, 2018
[49] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Hollnagel et al., 2015
[50] Reason, 2000; Carayon et al., 2014

technological safeguards and system redundancies. Examining both the causes of error and the mechanisms that detect and contain emerging problems provides valuable insight into safe clinical performance[51].

~~*Slips and Lapses:*~~

Slips and lapses are failures of execution rather than failures of knowledge.

A slip occurs when the intended action is correct but the wrong action is performed. Examples in anaesthesia include selecting the wrong syringe from an anaesthetic tray, connecting monitoring equipment to the incorrect port or pressing an incorrect button on an infusion pump.

A lapse involves a failure of memory. Examples may include forgetting prophylactic antibiotics following an interruption, omitting an antiemetic during emergence or failing to document a critical event.

These errors commonly occur during highly familiar activities and are frequently associated with interruptions, distractions, fatigue and excessive cognitive workload. Their occurrence highlights an important principle of human factors: expertise improves performance but does not eliminate vulnerability to attentional failures and memory errors[52].

Mistakes:

Mistakes occur when the intended action is inappropriate because the underlying decision or plan is incorrect.

For example, severe hypotension following induction may initially be attributed to anaesthetic medications, leading to escalating vasopressor administration when the underlying cause is actually anaphylaxis or occult haemorrhage. Similarly, persistent desaturation following intubation may be attributed to the preceding airway difficulty, delaying recognition of alternative causes.

A structured D.O.P.E. check—used in some anaesthesia settings to prompt assessment for disconnection, obstruction, positioning and equipment-related causes—can broaden the diagnostic search and reduce fixation on the initial explanation.

At the time decisions are made, these actions may appear entirely logical based on the information available. Human factors therefore emphasises understanding not only what decision was made, but also why that decision made sense within the clinical context[53].

Violations and Workarounds:

Violations involve deliberate deviations from accepted procedures, policies or guidelines. Importantly, such deviations should not automatically be interpreted as reckless behaviour.

In healthcare, workarounds frequently emerge because clinicians are attempting to maintain patient care despite environmental constraints. Examples may include bypassing a checking process because of extreme time pressure, modifying standard procedures because equipment is unavailable or developing informal practices to compensate for organisational limitations.

Although often well intentioned, repeated workarounds may gradually become normalised and unintentionally reduce safety margins. Human factors therefore seeks to understand why deviations occur and what system conditions promote them, rather than assuming that procedural non-compliance reflects individual misconduct[54].

Fixation Errors:

[51] Hollnagel et al., 2015; Wears et al., 2015
[52] Reason, 2000; Flin et al., 2008; Grundgeiger & Sanderson, 2009
[53] Reason, 2000; Croskerry, 2003
[54] Reason, 2000; Carayon et al., 2014

One of the most significant cognitive vulnerabilities in anaesthesia is fixation.

Fixation occurs when attention becomes excessively focused on one explanation while other possibilities are overlooked. Under conditions of stress and high cognitive workload, clinicians may become committed to an initial diagnosis or intervention despite evidence suggesting an alternative explanation.

Persistent desaturation following induction, for example, may lead teams to focus exclusively on intubation while failing to recognise circuit disconnection or severe bronchospasm. Similarly, refractory hypotension may be attributed solely to anaesthetic medications while evolving anaphylaxis remains unrecognised.

Fixation narrows situational awareness and reduces cognitive flexibility. Consequently, the ability of team members to question assumptions and contribute alternative perspectives becomes a critical safety defence[55].

~~*Medication Errors:*~~

Medication administration represents one of the most vulnerable areas of anaesthesia practice. Clinicians routinely prepare and administer potent medications with narrow therapeutic margins, frequently under conditions of time pressure and considerable cognitive demand[56].

Medication errors may occur during prescribing, preparation, labelling, selection or administration processes. Examples include selecting an incorrect ampoule, drawing up an incorrect concentration or administering medication through an unintended route.

Importantly, medication incidents rarely arise because clinicians lack pharmacological knowledge. More commonly, they emerge from interactions between human cognition and system design. Similar packaging, interruptions during preparation, poor workspace organisation, inconsistent labelling and excessive workload all increase vulnerability to error[57].

Consequently, strategies such as colour-coded labelling, standardised medication layouts and independent verification processes have become increasingly important components of medication safety[58].

Communication Failure and Loss of Situational Awareness:

Communication failures remain among the leading contributors to adverse events in healthcare. Information may be omitted during handovers, misunderstood during emergencies or lost among competing demands and environmental distractions[59].

Similarly, situational awareness may deteriorate when clinicians become excessively task-focused and lose appreciation of the broader clinical picture. Fatigue, cognitive overload, interruptions and fixation all impair the ability to perceive, interpret and anticipate developing events[60].

Importantly, situational awareness is fundamentally a team process rather than an individual responsibility.

Anaesthetists, Anaesthetic Technicians and nursing staff all contribute to shared awareness by monitoring equipment, observing patient responses and communicating concerns. An Anaesthetic Technician recognising an unexpected capnography change, questioning low tidal volumes or identifying discrepancies in medication preparation may detect developing problems before physiological deterioration occurs[61].

Many adverse events are prevented precisely because another team member notices something unexpected and communicates their concern[62].

[55] Croskerry, 2003; Flin et al., 2008
[56] Cooper et al., 2002; Merry & Cooper, 2018
[57] Reason, 2000; Catchpole et al., 2008; Grundgeiger & Sanderson, 2009
[58] Cooper et al., 2002; Merry & Cooper, 2018
[59] Lingard et al., 2004; Kohn et al., 2000
[60] Endsley, 1995; Flin et al., 2008
[61] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[62] Edmondson, 1999; Edmondson, 2019

Error Recovery and Resilience:

Perhaps the most important insight from human factors research is that healthcare systems function successfully far more often than they fail.

Errors and near misses occur regularly within complex systems, yet patient harm remains relatively uncommon because clinicians continuously identify, intercept and recover from developing problems. This capacity to detect and recover from error is referred to as resilience[63].

Within anaesthesia, resilience is demonstrated when clinicians identify equipment malfunctions before patient harm occurs, recognise medication errors prior to administration, challenge assumptions during crises or successfully adapt to unexpected events.

The study of error therefore extends beyond understanding why things go wrong. Equally important is understanding why things usually go right despite complexity, uncertainty and continual exposure to hazards[64].

Anaesthesia's exceptional safety record is not evidence that human error has been eliminated. Rather, it reflects the remarkable adaptive capacity of clinicians and the presence of multiple system defences that support detection, recovery and resilience[65].

Understanding how errors develop reinforces a central principle of human factors science: human errors are inevitable consequences of operating within complex systems, but patient harm is not[66].

Table 1. Common Types of Human Error in Anaesthesia

Type of Error	Example in Anaesthesia	Common Contributors	Potential Impact
Slip	Selecting the wrong syringe from the anaesthetic tray	Distraction, interruption, similar packaging, look-alike vials	Incorrect medication prepared or administered
Lapse	Omitting prophylactic antibiotics after induction	Memory overload, fatigue, interruption	Delay or omission of necessary treatment
Mistake	Treating anaphylaxis as anaesthetic-induced hypotension	Cognitive bias, fixation, incomplete information, time pressure	Inappropriate treatment with potential for harm
Violation	Bypassing a safety check because of time pressure	Workarounds, production pressure, normalised Deviations	Increased risk of error or missed hazard
Fixation	Focusing on difficult intubation while missing circuit disconnection	Tunnel vision, stress, commitment to initial diagnosis	Delayed recognition of true underlying cause
Communication Failure	Important information omitted during handover	Hierarchy, assumptions, noise, distractions	Misunderstanding, delay in treatment or response

Anaesthetic Technicians: The Hidden Safety Net of High-Reliability Anaesthesia

Patient safety in anaesthesia is frequently attributed to clinical expertise, technological advancements and organisational systems. However, safe perioperative care does not depend upon the actions of a single clinician.

[63] Hollnagel et al., 2015; Wears et al., 2015
[64] Hollnagel, 2018; Hollnagel et al., 2015
[65] Wears et al., 2015; Weick & Sutcliffe, 2015
[66] Reason, 2000; Hollnagel et al., 2015

Rather, it emerges from coordinated interactions between professionals who collectively monitor, anticipate, communicate and respond to changing clinical situations[67].

Within Australia and New Zealand, Anaesthetic Technicians and Anaesthetic Healthcare Practitioners contribute specialised clinical and technical expertise in patient assessment and monitoring, equipment management, troubleshooting, perioperative support and emergency response. Viewed through a human factors lens, these practitioners function as independent safety barriers, cognitive partners and resilience resources that strengthen system performance and reduce opportunities for patient harm[68].

~~*Anaesthetic Technicians as Distributed Safety Intelligence:*~~

Modern patient safety science increasingly recognises that cognition and resilience are distributed across teams rather than residing solely within individuals. Safe performance in complex environments depends upon multiple people simultaneously observing, interpreting and responding to evolving clinical situations[69].

Anaesthetic Technicians contribute to this distributed safety intelligence by functioning as additional sources of situational awareness, technical expertise and adaptive support within the operating theatre. Through continuous observation of patient physiology, equipment function and procedural progression, they frequently identify developing problems before they become adverse events[70].

Examples of this distributed safety role include:

• recognising progressively increasing airway pressures suggesting bronchospasm;

• identifying deterioration in capnography before significant haemodynamic compromise occurs;

• recognising a disconnected breathing circuit during patient repositioning;

• identifying incorrect equipment setup during machine preparation;

• questioning discrepancies in medication preparation or labelling.

These interventions frequently occur quietly and may remain undocumented. However, they represent important examples of system resilience and illustrate how patient safety often depends upon multiple individuals collectively monitoring for emerging risks[71].

Equipment Readiness and Standardisation:

The safe delivery of anaesthesia depends fundamentally upon the reliable performance of equipment and monitoring systems. Modern anaesthesia requires integration of anaesthetic workstations, physiological monitoring technologies, infusion devices and numerous ancillary systems. Failures within these systems may have immediate and potentially catastrophic consequences[72].

Anaesthetic Technicians play a central role in reducing these risks through equipment preparation, standardisation and verification processes[73].

Routine activities such as machine checks, monitoring calibration, equipment assembly and preparation of emergency airway equipment may appear procedural in nature; however, they represent critical layers of defence against patient harm.

From a human factors perspective, these activities function as proactive error management strategies. Identifying equipment failures before patient contact prevents latent conditions from progressing to active

[67] Carayon et al., 2014; Hollnagel et al., 2015
[68] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[69] Carayon et al., 2014; Hollnagel et al., 2015
[70] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023; Endsley, 1995
[71] Hollnagel et al., 2015; Wears et al., 2015
[72] Merry & Cooper, 2018
[73] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023

failures during clinical care. Furthermore, standardised equipment layouts and preparation processes reduce cognitive workload by creating predictable and familiar working environments[74].

A difficult airway trolley arranged consistently between theatres, for example, reduces time spent searching for equipment during emergencies and allows cognitive resources to remain focused on patient management.

Equipment Troubleshooting and Cognitive Offloading:

The increasing sophistication of anaesthesia technology has substantially increased the cognitive demands placed upon clinicians. Anaesthetists must simultaneously manage patient physiology and understand complex monitoring systems, ventilators and integrated software interfaces[75].

Anaesthetic Technicians frequently possess highly specialised knowledge regarding equipment functionality, limitations and troubleshooting processes. During equipment malfunctions, they often provide critical expertise that facilitates rapid identification and resolution of technical problems[76].

This contribution becomes particularly important during emergencies.

Consider sudden loss of capnography during laparoscopic surgery. While the anaesthetist focuses on patient assessment and airway management, the Anaesthetic Technician may simultaneously investigate circuit integrity, carbon dioxide sampling lines, breathing system connections and equipment functionality.

This distribution of tasks reduces cognitive demands on the anaesthetist and allows greater attention to remain focused on patient assessment and decision-making.

From a human factors perspective, this process represents cognitive offloading. By distributing responsibilities across team members, overall system performance is enhanced and vulnerability to cognitive overload is reduced[77].

Shared Situational Awareness:

Situational awareness is frequently described as the ability to perceive information, understand its significance and anticipate future events[78]. Within anaesthesia, situational awareness underpins safe performance because clinicians must continuously monitor physiological trends and recognise subtle changes before significant deterioration occurs.

Maintaining situational awareness becomes increasingly difficult during induction, emergence and critical incidents, where attentional resources are heavily consumed by task demands[79].

Anaesthetic Technicians contribute substantially to shared situational awareness by functioning as additional observers within the clinical environment. Through continuous monitoring of equipment, patient responses and environmental factors, they provide independent sources of information that complement and enhance the awareness of other team members[80].

Many adverse events are prevented because another team member notices something unexpected and communicates their concern.

A technician recognising progressively decreasing oxygen saturation during patient repositioning, an unusual capnography trace following circuit manipulation or increasing airway pressures during laparoscopic insufflation may detect subtle changes before they progress to patient harm.

[74] Reason, 2000; Carayon et al., 2014
[75] Flin et al., 2008; Young et al., 2015
[76] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025
[77] Carayon et al., 2014; Hollnagel et al., 2015
[78] Endsley, 1995
[79] Flin et al., 2008
[80] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025

Safe anaesthesia therefore depends not solely upon individual vigilance but upon collective awareness and collaborative interpretation of evolving information[81].

~~*Crisis Resource Management and Emergency Response:*~~

Anaesthesia is characterised by periods of routine activity interrupted by episodes of rapidly escalating complexity. Unexpected airway emergencies, malignant hyperthermia, massive haemorrhage and cardiovascular collapse transform stable environments into highly stressful situations requiring immediate coordinated action.

Effective management of these events depends not only upon technical expertise but also upon communication, leadership, task distribution and effective use of available resources[82].

Anaesthetic Technicians play integral roles in these responses. They prepare emergency medications and equipment, retrieve additional resources, assist with procedural interventions and anticipate clinical requirements[83].

During malignant hyperthermia, for example, technicians may prepare dantrolene, obtain cooling equipment, coordinate additional resources and assist with equipment preparation while the anaesthetist leads diagnosis and treatment.

These activities reduce cognitive workload, facilitate task prioritisation and improve team performance under conditions of extreme stress.

Their contribution during emergencies therefore extends beyond assistance; they actively contribute to team resilience and adaptive capacity[84].

Independent Verification and Error Interception:

Human factors science recognises that errors are inevitable within complex systems. Consequently, safe systems incorporate multiple layers of defence designed to detect and intercept errors before they reach patients[85].

Anaesthetic Technicians frequently function as independent checking mechanisms within the perioperative environment[86].

Examples include identifying incorrectly configured equipment, recognising discrepancies in medication preparation, noticing omissions in monitoring or questioning unexpected physiological changes.

Although these interventions may appear minor, they represent critical opportunities for error interception.

Many near misses within anaesthesia are successfully prevented because another team member notices something unexpected and communicates their concern.

Through independent observation and verification, Anaesthetic Technicians function as essential components of system redundancy and resilience[87].

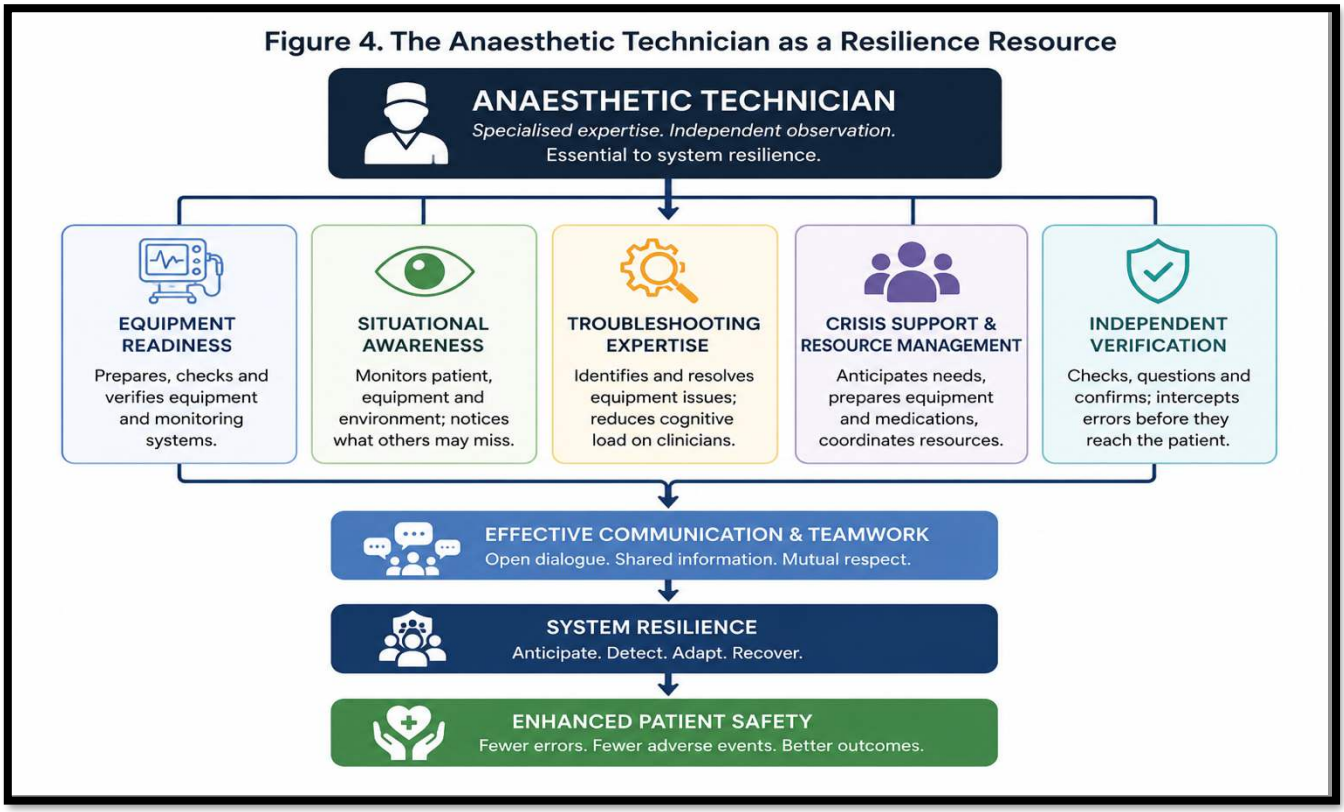
Beyond Technical Assistance:

The contribution of Anaesthetic Technicians extends far beyond equipment preparation and procedural assistance.

[81] Endsley, 1995; Hollnagel et al., 2015
[82] Gaba, 2000; Fletcher et al., 2003
[83] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025
[84] Hollnagel et al., 2015; Wears et al., 2015
[85] Reason, 2000
[86] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025
[87] Reason, 2000; Hollnagel et al., 2015

Through equipment readiness, troubleshooting, distributed observation, shared situational awareness, independent verification and crisis support, these practitioners strengthen system resilience and provide additional layers of defence against patient harm[88].

Viewed through a human factors lens, Anaesthetic Technicians represent a hidden safety net within high-reliability anaesthesia practice. Their contribution demonstrates an important principle of patient safety science: safe performance in complex environments depends not upon perfect individuals, but upon resilient teams capable of collectively anticipating, detecting and responding to inevitable challenges[89].



Building High-Reliability Anaesthesia

Anaesthesia is frequently described as a high-reliability specialty because it consistently delivers safe patient care despite operating in environments characterised by complexity, uncertainty and significant consequences of failure. Clinicians routinely administer potent medications, induce reversible unconsciousness, manipulate physiology and manage potentially catastrophic emergencies while maintaining remarkably low rates of serious adverse events[90].

This level of safety is not achieved by eliminating human error or expecting flawless performance. Rather, it reflects the deliberate development of systems that recognise human limitations and support clinicians in anticipating, detecting and recovering from inevitable challenges[91].

Lessons from high-reliability industries such as commercial aviation and nuclear power provide valuable insights into how patient safety can be further strengthened within anaesthesia[92].

Preoccupation with Failure:

[88] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[89] Hollnagel et al., 2015; Wears et al., 2015; Weick & Sutcliffe, 2015
[90] Haller et al., 2011; Merry & Cooper, 2018
[91] Hollnagel et al., 2015; Weick & Sutcliffe, 2015
[92] Helmreich & Merritt, 2000; Weick & Sutcliffe, 2015

High-reliability organisations remain continually alert to the possibility of failure. The absence of adverse events is not interpreted as evidence that systems are perfect. Instead, near misses, small deviations and minor incidents are viewed as opportunities for learning and improvement[93].

Within anaesthesia, this principle is demonstrated through incident reporting, morbidity and mortality reviews, equipment audits and investigation of near misses.

A syringe swap identified prior to medication administration, an incorrectly configured ventilator recognised during machine checks or an omitted monitoring lead detected before induction all represent valuable opportunities to identify vulnerabilities and strengthen system defences before patient harm occurs.

~~*Sensitivity to Operations:*~~

High-reliability organisations maintain constant awareness of what is occurring on the frontline[94].

Anaesthesia requires exceptional operational awareness. Clinicians continuously monitor physiological trends, observe patient responses, interpret surgical progression and anticipate future requirements.

Importantly, this awareness is shared across the multidisciplinary team.

An Anaesthetic Technician identifying progressively increasing airway pressures, a nurse recognising unexpectedly high blood loss or an anaesthetist observing subtle capnography changes all contribute to collective understanding of the evolving clinical situation[95].

Patient safety frequently depends upon the ability of teams to recognise small changes before they become significant problems.

Commitment to Resilience:

Not all failures can be prevented. Consequently, high-reliability systems invest heavily in developing adaptive capacity and recovery mechanisms[96].

Anaesthesia is characterised by periods of stability interrupted by episodes of rapidly escalating complexity. Unexpected difficult airways, malignant hyperthermia, anaphylaxis and major haemorrhage require clinicians to rapidly reassess information, reprioritise tasks and coordinate effective responses.

Simulation training, crisis resource management and multidisciplinary emergency exercises strengthen these adaptive capabilities by allowing teams to rehearse rare but critical events in psychologically safe environments[97].

Resilience is demonstrated not by avoiding every error or unexpected event, but by recognising problems early and adapting effectively when they occur[98].

Deference to Expertise:

High-reliability teams value expertise wherever it exists[99].

Although anaesthesia teams operate within professional structures and defined responsibilities, the individual with the most relevant information may not necessarily hold the most senior position.

[93] Weick & Sutcliffe, 2015
[94] Weick & Sutcliffe, 2015
[95] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Endsley, 1995
[96] Hollnagel et al., 2015; Hollnagel, 2018
[97] Gaba, 2000; Fletcher et al., 2003
[98] Hollnagel et al., 2015; Wears et al., 2015
[99] Weick & Sutcliffe, 2015

Anaesthetic Technicians frequently possess specialised knowledge regarding equipment functionality and troubleshooting processes. Nurses may identify workflow issues or subtle patient changes that others have not yet recognised. Anaesthetists contribute expertise in physiology, pharmacology and clinical decision-making[100].

High-reliability teams actively seek information from all members and encourage individuals to question assumptions and communicate concerns regardless of role or seniority. From a human factors perspective, cognition and resilience are distributed across multidisciplinary teams, and patient safety is strengthened when specialised knowledge is recognised and incorporated into collective decision-making[101].

During crises, additional perspectives often broaden situational awareness and prevent fixation on a single explanation or intervention. An Anaesthetic Technician identifying abnormal ventilator parameters during an airway emergency or questioning unexpected capnography changes may provide information that fundamentally alters team understanding and guides subsequent actions.

Deference to expertise therefore extends beyond professional courtesy. It represents a deliberate strategy for harnessing distributed safety intelligence and strengthening the adaptive capacity of high-reliability anaesthesia systems[102].

~~*Psychological Safety and Learning Culture:*~~

Perhaps the most important characteristic of high-reliability organisations is their commitment to learning.

Environments characterised by blame and fear discourage reporting, inhibit communication and increase the likelihood that vulnerabilities remain hidden. In contrast, psychologically safe cultures encourage individuals to ask questions, seek assistance, report mistakes and challenge decisions without fear of humiliation or retribution[103].

Within anaesthesia, psychological safety supports many of the behaviours essential to patient safety. Team members are more likely to communicate concerns, report near misses and contribute information when they believe their observations are respected and valued.

Importantly, psychological safety does not eliminate accountability or lower professional standards. Rather, it creates environments in which learning and accountability coexist[104].

High Reliability as Everyday Practice:

The principles of high reliability reinforce a fundamental reality of patient safety: safe anaesthesia does not depend upon perfect clinicians working in perfect systems.

Rather, safety emerges from resilient teams operating within systems deliberately designed to anticipate vulnerability, recognise emerging problems and recover before patient harm occurs[105].

Preoccupation with failure encourages vigilance and learning. Sensitivity to operations strengthens situational awareness. Commitment to resilience develops adaptive capacity. Deference to expertise values contributions from all team members. Psychological safety facilitates communication and continuous improvement[106].

Together, these principles shift the focus of patient safety away from perfection and towards resilience.

[100] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[101] Carayon et al., 2014; Hollnagel et al., 2015
[102] Weick & Sutcliffe, 2015; Hollnagel et al., 2015
[103] Edmondson, 1999; Edmondson, 2019
[104] Edmondson, 2019
[105] Hollnagel et al., 2015; Wears et al., 2015
[106] Weick & Sutcliffe, 2015; Edmondson, 2019

Ultimately, high reliability in anaesthesia is not the absence of error. It is the capacity of individuals, teams and organisations to anticipate, detect, adapt and recover in the face of inevitable challenges[107].

Table 2. High-Reliability Principles in Anaesthesia Practice

Principle	What It Looks Like in Anaesthesia
Preoccupation with Failure	Actively seeking and reporting near misses; reviewing incidents and equipment issues to identify and fix system vulnerabilities.
Sensitivity to Operations	Continuously monitoring patient physiology, equipment performance and workflow; noticing small changes before they become big problems.
Commitment to Resilience	Training for rare but critical events; using checklists, standardisation and crisis resource management to prepare, adapt and recover.
Deference to Expertise	Valuing expertise wherever it exists; encouraging all team members, regardless of role, to speak up and share concerns.
Psychological Safety	Creating an environment where questions, concerns and errors can be raised openly without fear of blame or judgment.

The A-DAPT Framework for Safe Anaesthesia

The principles discussed throughout this paper reinforce a fundamental reality of patient safety: safe anaesthesia is not achieved because clinicians are incapable of error. Rather, it is achieved because resilient teams and systems anticipate vulnerability, recognise developing problems and recover before harm occurs[108].

Human factors science demonstrates that patient safety emerges from interactions between people, technologies, environments and organisations. Cognitive overload, interruptions, fatigue and communication failures cannot be completely eliminated. However, their consequences can be substantially reduced through deliberate system design and effective teamwork[109].

Throughout modern anaesthesia practice, clinicians continuously adapt to uncertainty and complexity. Anaesthetists, Anaesthetic Technicians and nursing staff collectively monitor patients, anticipate complications, identify emerging risks and coordinate responses to unexpected events. Safe performance therefore depends not upon individual perfection, but upon the capacity of teams to function as adaptive and resilient systems[110].

These principles can be summarised using the A-DAPT framework for safe anaesthesia:

A – Anticipate Risk
Recognise vulnerabilities, prepare equipment, identify high-risk patients and plan contingencies before problems occur.

D – Detect Early Change
Continuously monitor patient physiology, equipment function and environmental conditions to recognise subtle deterioration and emerging hazards.

[107] Hollnagel, 2018; Weick & Sutcliffe, 2015
[108] Hollnagel et al., 2015; Wears et al., 2015
[109] Carayon et al., 2014; Reason, 2000
[110] Hollnagel, 2018; Weick & Sutcliffe, 2015

A – Acknowledge Concerns
Encourage all team members to communicate observations, question assumptions and raise concerns regardless of role or seniority.

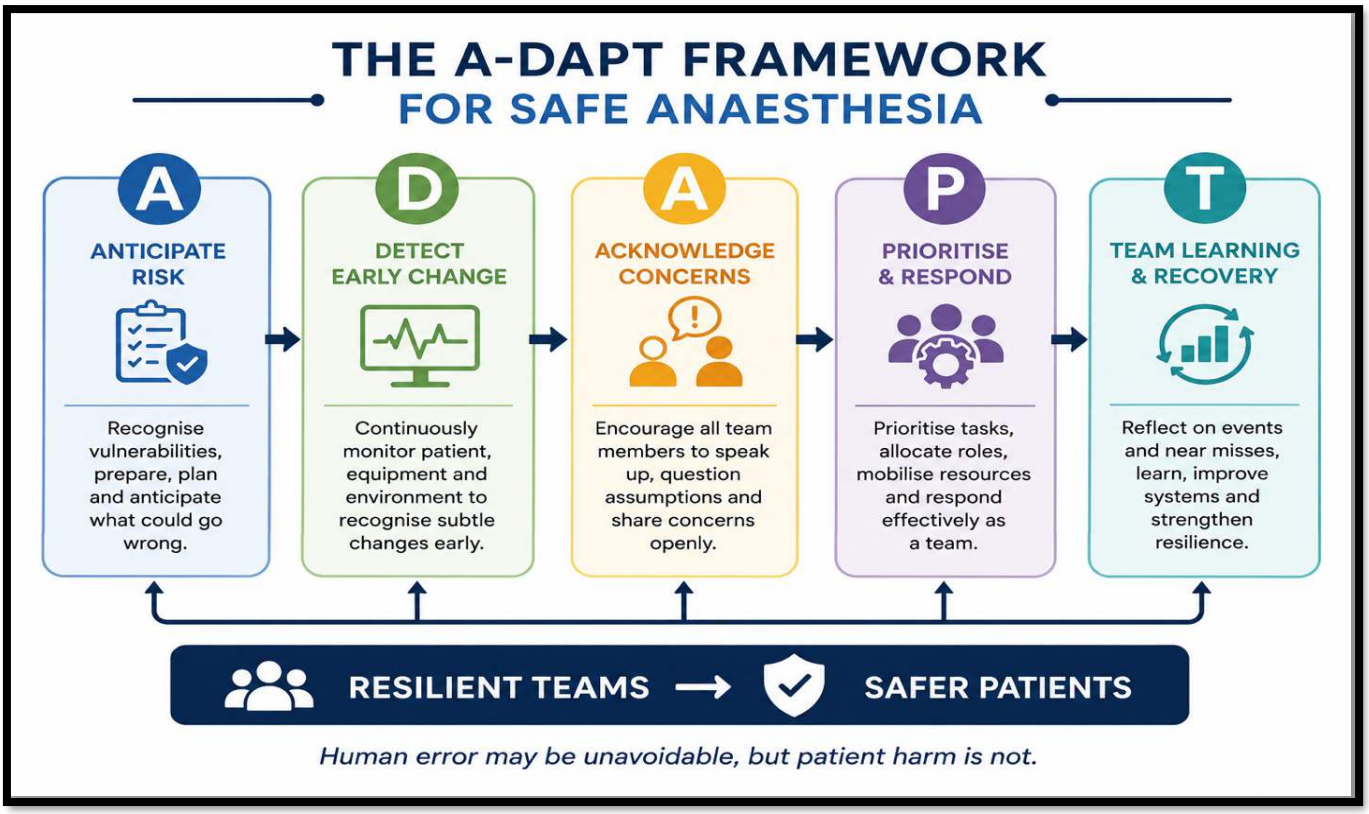
P – Prioritise and Respond
Allocate tasks, mobilise resources and implement interventions using effective communication and teamwork principles.

T – Team Learning and Recovery
Reflect on incidents and near misses, identify opportunities for improvement and strengthen system resilience through continuous learning.

Importantly, Anaesthetic Technicians contribute to every stage of this framework through equipment readiness, independent observation, troubleshooting expertise, verification processes and crisis support. Their role extends beyond technical assistance. Anaesthetic Technicians function as distributed safety intelligence within high-reliability systems, expanding situational awareness, reducing cognitive burden and strengthening the capacity of teams to anticipate, detect and recover from error[111].

Patient physiological resilience may also provide a brief window in which emerging problems can be recognised and corrected; however, this capacity is variable and cannot substitute for robust system defences.

The pursuit of perfect human performance in anaesthesia is therefore an illusion. Safe anaesthesia ultimately depends upon resilient teams that recognise human limitations and deliberately create systems capable of anticipating, detecting and recovering from inevitable challenges. Human error may be unavoidable, but patient harm is not[112].



[111] Australian Anaesthesia Allied Health Practitioners [AAAHP], 2025; Medical Sciences Council of New Zealand, 2023
[112] Holnagel et al., 2015; Weick.& Sutcliffe, 2015