



MALAYSIAN SOCIETY OF ANAESTHESIOLOGISTS

YEAR BOOK 2025/2026
Future-ready Anaesthesia

MALAYSIAN SOCIETY OF ANAESTHESIOLOGISTS



Yearbook 2025/2026

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Foreword

Dear Colleagues and Esteemed Readers,

It is both a privilege and an honour to welcome you to the latest edition of the Malaysian Society of Anaesthesiologists (MSA) Year Book.

This year's theme, **“The Future-Ready Anaesthesia”** comes at a pivotal moment for our specialty. As the medical landscape evolves through technological breakthroughs, shifting demographic demands, and rapid developments in perioperative medicine, our role extends far beyond the traditional boundaries of the operating theatre. We are transforming into holistic perioperative physicians, clinical leaders, and innovators who drive patient safety and excellence in outcomes.

Being future-ready is not merely about adopting state-of-the-art technology or modern pharmacological advancements; it is a mindset. It requires us to cultivate resilience, embrace continuous learning, and integrate data-driven insights into our daily clinical practice. From artificial intelligence and advanced haemodynamic monitoring to sustainable, eco-friendly anaesthetic practices, the future calls on us to adapt proactively while remaining steadfast in our commitment to compassionate, high-quality patient care.

This Year Book stands as a testament to the dedication, intellectual vigour, and collective accomplishments of our vibrant community over the past year. Within these pages, you will find a celebration of our milestones, critical reflections on emerging trends, and inspiring contributions from colleagues across the nation who are actively shaping the trajectory of Malaysian anaesthesiology.

I extend my deepest gratitude to the Editorial Board Of the Year Book for their tireless efforts in bringing this volume to fruition. My heartfelt thanks also go to every member of the MSA whose commitment to excellence keeps our Society strong, progressive, and globally competitive.

As you read through this edition, I hope it sparks meaningful conversations, inspires new ideas, and renews your passion for our extraordinary profession. Together, let us step boldly into the future, united in our mission to elevate the standards of anaesthesiology, critical care, and pain medicine in Malaysia.

Wishing you all an inspiring and reflective read.

Dr Hasmizy Muhammad

President,
Malaysian Society of Anaesthesiologists

Preface

It has been a great privilege to assemble the MSA Year Book 2025/2026. While considering potential topics, we felt strongly drawn to the theme of sustainability, safety, and future-readiness, which closely align with the current needs of our practice.

We were delighted that so many of the authors we approached were eager to share their fresh insights and perspectives on this theme. This enthusiastic response demonstrates that our fellow anaesthesiologists are highly adaptable to the evolving changes in our field. Our role was simply to weave these ideas together, a task made possible by the invaluable support of fraternity members who served as independent reviewers.

In this Year Book, we explore the changing landscape of sustainable practices. Given that green anaesthesia has been a recurrent theme over the past three years, we felt it vital to examine the safe use of medications and resources as core components of sustainability. Furthermore, we invite the fraternity to consider evolving practices such as robotic surgery and point-of-care testing like ROTEM. It is time to embrace these advancements rather than dismissing them as costly or restricted to major tertiary centres. A future-ready anaesthesiologist understands that keeping the broader picture in view benefits everyone in the long term. Finally, we address the nuances of artificial intelligence (AI). While it is a subject some may tiptoe around, AI is not a competitor to be feared, but rather a complementary partner in our practice.

We hope you enjoy this edition. Traditionally, the publication has been “by the anaesthetist, and for the anaesthetist”. In line with collaborative practices, we are pleased to have the voice of the surgeons too.

Associate Professor Dr Chaw Sook Hui
Dr Priscilla A/P Manymuthu
Dr Ahmad Fariz bin Elias

Editors
MSA Year Book 2025/2026

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Part I

Perioperative Management and Patient Safety

Robotic Anaesthesia: Replacing or Refining the Anaesthesiologist?

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KEY POINTS

- **Role Refinement:** Automation in anaesthesia aims to refine the anaesthesiologist's role by managing repetitive tasks, rather than replacing human clinicians.
- **Pharmacological Robots:** These systems, including advanced closed-loop delivery models, autonomously adjust drug administration to maintain physiological targets.
- **Mechanical Robots:** Designed to assist with physically demanding procedures, these devices improve precision during tasks like tracheal intubation and regional nerve blocks.
- **Cognitive Robots:** Utilizing artificial intelligence, these systems provide real-time clinical decision support and predict critical events, such as impending hypotension.
- **Implementation Challenges:** Widespread adoption is currently hindered by issues surrounding legal accountability, the risk of clinician deskilling, data privacy, and global health disparities.
- **Future Outlook:** The future of perioperative care depends on human-machine collaboration, balancing algorithmic accuracy with essential human crisis-management skills.

1.1 Introduction

The field of anaesthesia has undergone profound transformation since the first public demonstration of ether anaesthesia in 1846.[1] Over the decades, advances in pharmacology, monitoring, and technology have continuously refined the practice. From the introduction of pulse oximeter to development of inhalational vaporiser and Target-Controlled Infusion (TCI) system, anaesthesiologists have consistently adopted new tools into the practice with the aim of enhancing patient safety and perioperative outcomes.[2]

In recent years, the emergence of robotic and automated anaesthesia systems, powered by artificial intelligence (AI), machine learning, and sophisticated control algorithms, has prompted a re-evaluation of the anaesthesiologist's role. These technologies bring greater precision, consistency and efficiency, but also raise questions about professional identity, ethical responsibility, and the boundaries of automation in medicine.

1.2 What is Robot?

The word 'robot' appeared, for the first time when the writer Karel Capek introduced it in his play 'Rossum's Universal Robots' in 1921. The original Czech word 'robota' means a slave who joyfully does any labour needed to be done, as the author described, while humans can enjoy their life without concerns.[3] The introduction of robots in medicine is not new, and the history of surgical robots began in 1985 with the Unimation Puma 200 robot used to perform computed-tomography-guided brain tumour biopsies.[4]

In modern anaesthesia, a robot is defined as any automatically operated machine or algorithmic system that replaces specific human efforts, though it may not resemble a human being in appearance or function.[4, 5]

One of the first questions that appears in most colleagues' mind when robotic anaesthesia is discussed is "are we going to lose our jobs?" However, modern medical automation is designed to refine, not replace, the clinicians. While machines are excellent at processing large amounts of data and performing repetitive tasks for hours without becoming fatigue or distracted, human clinicians possess the flexibility, empathy, and crisis-management skills needed to handle unexpected medical emergencies.[6] Therefore, robotic anaesthesia aims to take over routine, tiring tasks and frees up the anaesthesiologist's mental energy to focus on higher-level patient care.

1.3 Automation in Anaesthesia Practice

To critically evaluate how robotic anaesthesia is able to enter the daily practice allowing a smooth transformation from the present state towards the future of anaesthesia, a systematic classification of level of current technologies needs to be established.[5] With reference of the automotive industry's Society of Automotive Engineers (SAE) levels of driving automation,[7] a similar framework for anaesthesia practice can be proposed (Table 1.1).

Presently, automation in the clinical field of Anaesthesiology is at the Level 2 and 3 while vigorous research and experiments are still in progress to testify the possibility of advancement to the higher levels. To fully understand this shift and what it means for patient safety, it is necessary to explore the three distinct categories of robotic systems currently integrating into the specialty:[8]

- i. Pharmacological Robot
- ii. Mechanical Robot
- iii. Cognitive Robot

1.4 Pharmacological Robots

Pharmacological robots represent the most mature category of automation in anaesthesia. These systems are invented to maintain patient's homeostasis by continuously adjusting the delivery of anaesthetic and vasoactive drugs to achieve a desired physiological target.[7]

1.4.1 The Evolution from Open-Loop to Closed-Loop Anaesthesia Control Systems

The foundation of pharmacological robots lies in Target-Controlled Infusion (TCI) systems. TCI utilizes population-based pharmacokinetic (PK) models to calculate the loading boluses and infusion rates required to achieve a targeted plasma or effect-site drug concentration.[9] While TCI significantly reduces the clinician's workload compared to manual calculations, it operates strictly as an "open-loop" system. A significant drawback of these systems is their lack of responsiveness to real-time physiological changes as they operate strictly based on the preset PK/PD model, which can lead to risks of over- or under-anaesthesia.[2] Additionally, open-loop systems rely on trained anaesthesiologists for monitoring and adjustments, increasing the possibility of operator-dependent errors.[7, 10]

To overcome the limitations of open-loop TCI, modern pharmacological robots utilize "closed-loop" control systems, often referred as Closed-Loop Anaesthesia Delivery Systems (CLADS). A closed-loop system

Table 1.1: Proposed Levels of Automation in Anaesthetic Practice

Level	Description	Clinical example	Anaesthesiologist's Role
Level 0: No Automation	Manual control of all variables	Syringe bolus of Propofol based on clinical judgement	Complete manual control and constant vigilance
Level 1: Driver Assistance	Automation of a specific task	Target-Controlled Infusion (TCI) pumps	Presets targets, monitors effect, adjusts targets manually
Level 2: Partial Automation	Combined automation of multiple tasks, but requires constant oversight	Co-administration of Propofol and Remifentanyl via open-loop TCI	Constant supervision; human is the primary decision-maker
Level 3: Conditional Automation	Closed-loop control of the anaesthetic state based on feedback	Closed-Loop Anaesthesia Delivery Systems (CLADS)	Human acts as a fallback system. Must intervene if the system encounters an error
Level 4: High Automation	System handles all aspects of maintenance and can safely stop or alter course without human input	Advanced AI systems predicting and treating hypotension autonomously (Prototype phase)	Human provides initial parameters and is out of the loop, acting only as a supervisor.
Level 5: Full Automation	Complete autonomous management from induction to emergence in all patients	Theoretical fully robotic	Currently scientifically and ethically unfeasible

continuously monitors a specific physiological variable, comparing it to a predefined clinician-set target, and autonomously adjusts the drug delivery pump to minimize the error between the measured parameters and the target.[11]

Early pharmacological robots operated as Single Input Single Output (SISO) systems, typically utilizing the Bispectral Index (BIS) to guide the infusion of a single hypnotic agent like Propofol or Remifentanyl. These systems proved highly effective at reducing target overshoot and undershoot compared to manual administration.[12]

However, general anaesthesia is a complex multi-dimensional state requiring the simultaneous management of hypnosis, analgesia, haemodynamic status and neuromuscular blockade. This complexity led to the introduction of Multiple Input Multiple Output (MIMO) systems (Figure 1.1). An outstanding example of a MIMO pharmacological robot is the McSleepy system. McSleepy independently and concurrently administers propofol, remifentanyl, and rocuronium by analysing multiple feedback loops, including BIS for hypnosis, Analgoscoring for pain, and phonomyography for muscle relaxation.[13, 14] Randomised controlled trials have demonstrated that MIMO systems like McSleepy delivers superior control of both anaesthesia and analgesia compared to manual administration, even during complex cardiac procedures.[15]

1.4.2 The lesson learnt from the Sedasys System

Pharmacological robots intended to help to refine the anesthesiologists' role. However, despite the significant advancements in closed-loop systems and their demonstrated superiority over manual control in terms of precision, safety, and patient outcomes, these systems have yet to reach wider adoption at the bedside clinical use.[16] The main barriers include the complexities of integrating physiological models, the requirement of highly reliable sensors, and the design challenges involved in creating robust control algorithms capable of adjusting to the unique needs of each patient. Additionally, the high costs of these systems, combined with the necessity for rigorous regulatory approvals, have slowed their introduction into daily clinical practice.[2, 17]

In addition, the historical failure of the Sedasys system (Johnson & Johnson) serves as an example that the attempt to utilize pharmacological robots to replace anaesthesiologists is still impossible. Sedasys was an FDA-approved automated propofol sedation system intended for use by gastroenterologists for procedural sedation during endoscopy in the absence of anaesthesiologists.[18] However, the machine could not proactively adjust sedation levels to match the expected discomfort of the procedure, nor could it manage a patient's airway if they became too deeply sedated. The withdrawal of Sedasys system highlights a fundamental truth: a pharmacological robot cannot replace the human's ability to rescue an airway, think critically, and

manage complex life-threatening crisis.[18, 19]

1.5 Mechanical Robots

Robots for surgery such as the DaVinci robot has been well established in clinical practice. These robots provide motorised, automated assistance for procedures that require high levels of manual skill. They help to steady the human hand thus removing tremor, increase the success rates of procedures, and minimise tissue damage.[20] While in anaesthesia, mechanical robots have been developed with the aim to facilitate airway management and regional anaesthesia.

1.5.1 Robotic Airway Management

Tracheal intubation is a critical skill that requires precise hand-eye coordination, anatomical knowledge, and the ability to adapt to unanticipated difficult airway.[21] Mechanical robots, notably the Kepler Intubation System (KIS) as shown in Figure 1.2, use a flexible robotic arm equipped with a videolaryngoscopy that is remotely operated by the doctor using a joystick.[22]

The theoretical advantages of KIS include:

- Infection control & safety: minimize exposure to patient with infectious disease by distancing outside the aerosol-generating zone, for example, in coronavirus disease (COVID-19).[8, 23]
- Eliminates hand shaking.
- Freeing the operator's hands to allow any other movement, such as adjustment of the mouth.
- Reduces operator fatigue and musculoskeletal strain during prolonged procedures.

However, this robot system is still very cumbersome to use, bulky, and clearly not at a commercial stage yet. The small pilot study, however, showed an acceptable success rate.[24]

Identifying the tracheal inlet relies on Artificial Intelligence (AI) for image recognition. Carlson et al collected images from operators intubating an airway mannequin using a standard videolaryngoscope and applied 4 different machine learning algorithms to yield an acceptable sensitivity of 70% and specificity of 90% for detecting glottis opening.[25] It is only a matter of time until the automated recognition of glottis and vocal cords will be integrated into commercial videolaryngoscopes to improve the prediction and management of difficult airways.

1.5.2 Robotic Regional Anaesthesia

Regional anaesthesia or nerve blocks is another field of anaesthesia that can greatly benefit from technology evolution. Currently, regional anaesthesia requires the operator to simultaneously interpret a moving

ultrasound image and accurately guide a needle. System like the Magellan robotic arm (Figure 1.3) was developed specifically to assist in this complex task by guiding a nerve block needle while communicating with ultrasound tracking software.[26]

Potential benefits of Robotic Regional Anaesthesia:

- Targeted Precision: Robotic assistance improves precision of needle tracking, ensuring safer delivery of local anaesthetic around critical area of nerves and blood vessels.[27]
- Accelerated Skill Acquisition: When tested on junior doctors, robotic-assisted nerve blocks resulted in much faster learning curves and less variation in performance between different doctors. This ensures a more uniform standard of care.[26, 28]
- Independent Operation: Advanced adaptations, such as the Safer Injection for Regional Anaesthesia (SAFIRA) device aim to eliminate the need for an assistant. The anaesthesiologist can independently control injection pressure via a foot pedal, which automatically stops the flow if pressure exceeds safe limits, thus reducing risk of nerve injury.[29]

Ultimately, mechanical robots do not replace the fundamental anatomical knowledge, the preoperative patient assessment, or the final medical decision and consent taking to perform anaesthetic procedure. Instead, they refine how the procedure is physically carried out, ensuring that the doctor's hands never tire during a long night shift, thus minimising human errors.

1.6 Cognitive Robots

The third category of robotic anaesthesia is cognitive robots, a system which transforms how anaesthesiologists process and react to clinical information. These systems function as an intellectual assistant which aids in analysing vast range of patients' data to provide real-time clinical suggestions, predictive warning and updated management guidelines.[30] Modern operating theatres are highly data-dense environments, and human cognition & physicality are naturally limited when continuously monitoring and tracking multiple physiological parameters over long hours.

To overcome these limitations, cognitive robots are deployed across three primary modalities:

■ Clinical Decision Support Systems (CDSS):

- *Function:* These systems utilise preset algorithms to interpret preoperative laboratory results, electronic health records, and surgical checklists, ensuring compliance to protocols.[31]

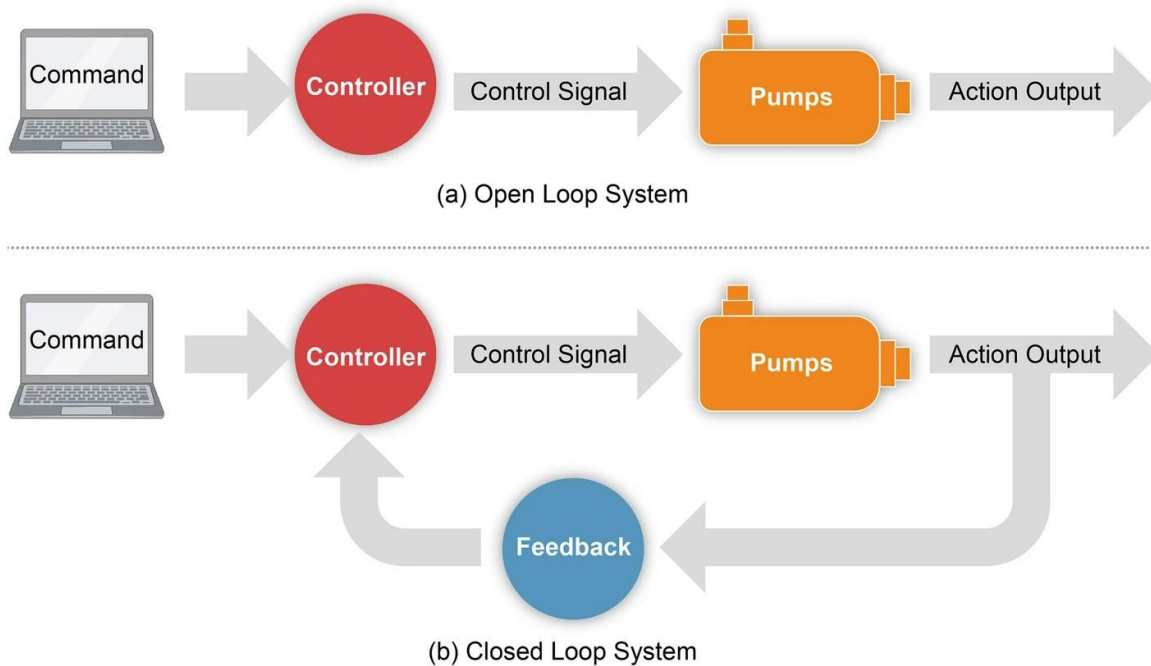


Figure 1.1: Comparison of open-loop and closed-loop control systems in automated anaesthesia. Adapted from “Advances in automated anaesthesia: a comprehensive review”, by Cai X et al, 2025, *Anesthesiology and Perioperative Science*, (2025) 3:3, Page 3, with permission from Springer Nature, Licenced under CC BY 4.0.

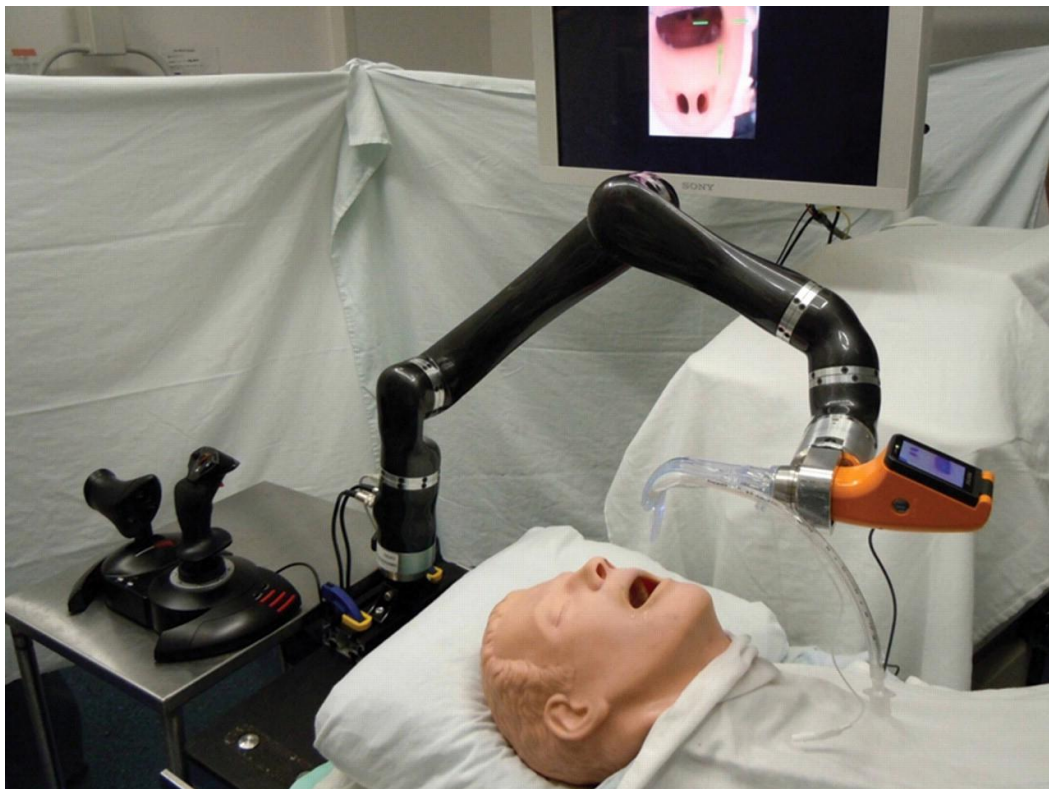


Figure 1.2: The Kepler Intubation System consisting of a robotic arm, a joystick, and a mounted videolaryngoscope. Adapted from “First robotic tracheal intubations in humans using the Kepler intubation system”, by Hemmerling, T. M. et al., 2012, *British Journal of Anaesthesia*, 108 (6): 1011—16 (2012), page 1013 — with permission from “Elsevier”.

- *Clinical Application:* Platforms like SmartPilot View and Navigator act as advanced advisory displays, applying pharmacokinetic models to map complex drug interactions and predict the depth of anaesthesia, enabling proactive anaesthetic strategy and planning.[31, 32]
- *Key Benefit:* By transforming static alarms into “smart alarms” that analyse multiple vital signs simultaneously, CDSS drastically reduces false alarm rates, hence effectively



Figure 1.3: The Magellan Robotic System consists of 3 main components: a joystick, a robotic arm and a software control system. Adapted from "First robotic ultrasound-guided nerve blocks in humans using the Magellan system Hemmerling, by Thomas M., et al. 2013, *Anesthesia & Analgesia*, Volume 116 Number 2, Page 492, with permission from Wolters Kluwer Health, Inc."

mitigating alarm fatigue among healthcare personnel.[33]

■ **Predictive Artificial Intelligence and Machine Learning:**

- *Function:* These data-driven cognitive robots integrate complex physiological parameters, analyse trends, and provide prediction of critical incidents.
- *Clinical Application:* A key example is the Hypotension Predictive Index (HPI), which analyses arterial blood pressure waves to accurately predict and alert low blood pressure events 10 to 15 minutes before they occur.[34]
- *Key Benefit:* This technology is transforming anaesthesia from reactive to predictive medicine, allowing anaesthesiologists to intervene early and thus avoid life-threatening complications.[35]

■ **Generative AI and Large Language Models (LLMs):**

- *Function:* The newest generation of cognitive robotics incorporates specialised medical AI language models acting as real-time, interactive clinical assistants.
- *Clinical Application:* During preoperative assessments, conversational AI such as Chat-Generative Pre-trained Transformers and medical chatbots can assist with patient interactions, analyse complex medical histories, and suggest customised anaesthetic plans according to updated guidelines.[36, 37]

- *Key Benefit:* These tools reduce human bias, prevent memory lapses, and instantly bridge sudden knowledge gaps, ensuring evidence-based and meticulously tailored care delivery.[36]

Cognitive robots refine the anaesthesiologist by eliminating cognitive biases, preventing memory lapses, and bridging the knowledge gaps. The AI can provide the predictive insight and data analysis, but the clinicians must interpret and infer if the technology-driven analysis is relevant to the specific patient, ultimately deciding whether to execute the suggested intervention.

The summary of current progress of major robotic systems in anaesthesia is shown in Table 1.2.

1.7 Future Challenges

Despite the immense potential of automated anaesthesia, several challenges must be addressed before extensive clinical adoption can occur:

- **Data Privacy and Security:** Generating intelligent algorithms requires a large-scale collection of data, raising the concern of patients' medical privacy. Federated learning, a decentralized AI training approach offers a promising solution by allowing hospitals to train AI models collaboratively while keeping sensitive patient data strictly local and secure.[38]
- **Ethical and Medicolegal Accountability:** The integration of AI poses complex questions regarding responsibility in the event of a medical error. If an autonomous system administers an

Table 1.2: Current Status of Robotic Systems in Anaesthesia

System	Type of Robot	Primary Function	Role Refinement	Current Status
TCI	Pharmacological (Open-Loop)	Delivers drug infusions via PK/PD models.	Reduces burden of manual dose calculations.	Commercially Available
CLADS	Pharmacological (SISO Closed-Loop)	Adjusts propofol delivery via continuous BIS feedback.	Prevents target overshoot and expedites wake-up times.	Early Commercial
McSleepy	Pharmacological (MIMO Closed-Loop)	Automates hypnosis, analgesia, and neuromuscular blockade.	Eliminates manual control of infusion & aids haemodynamic control.	Experimental
Kepler Intubation System	Mechanical	Joystick-operated robotic arm for intubation.	Improves airway management.	Experimental
Magellan System	Mechanical	Robotic arm for ultrasound-guided nerve blocks.	Accelerates learning curves and standardises needle tracking.	Experimental
SmartPilot View	Cognitive (CDSS)	Displays predicted drug synergies and anaesthetic depth.	Enhances situational awareness to prevent overdosing.	Commercially Available
Hypotension Predictive Index	Cognitive (Data-Driven AI)	Predicts hypotensive events.	Shifts care from reactive to proactive safeguarding.	Commercially Available
Sedasy (Historical)	Pharmacological / Cognitive	Semi-automated propofol sedation for endoscopy.	Emphasised the necessity of human presence for emergency crisis.	Discontinued

PK, Pharmacokinetics; PD, Pharmacodynamics; SISO, Single Input Single Output; MIMO, Multiple Input Multiple Output; CDSS, Clinical Decision Support System; AI, Artificial Intelligence.

incorrect dose that harms a patient, assigning liability towards the anaesthesiologist, hospital, or software developer requires clear and robust legal frameworks. The governance of AI in healthcare must rely on strict principles of fairness, accountability, sustainability, and transparency.[39]

- **Deskilling and Deterioration of Core Competencies:**

As automation assumes an increasing share of routine anaesthetic tasks, there is a genuine risk that future clinicians may acquire insufficient hands-on experience with basic skills such as manual drug titration, direct laryngoscopy, and crisis recognition without algorithmic prompting. The aviation industry has demonstrated that over-dependence on autopilot systems can impair pilots' ability to respond decisively when automation fails. A similar problem may emerge in anaesthesiology if training programmes do not deliberately preserve exposure to non-automated techniques. Structured simulation, adequate training in low-automation environments, and competency-based assessment frameworks will be essential to ensure that future anaesthesiologist remains a capable clinician, not merely a system supervisor.[40]

- **System Reliability and Failure Modes:**

Closed-loop and AI-driven systems are critically dependent on the continuous, accurate output of physiological sensors. Artefact, signal dropout, sensor displacement, or hardware malfunction can cause the system to act upon erroneous data, potentially delivering harmful drug doses or failing to respond to a deterioration in the patient's condition. Unlike a human clinician who may intuitively recognise that a monitor reading is implausible, an algorithm will process false data with the same confidence as true data unless robust outlier detection is incorporated into its design. Safe deployment of these systems therefore demands rigorous engineering standards, mandatory fail-safe mechanisms that default to human control upon sensor failure, and clear protocols for intraoperative troubleshooting. Regular device maintenance, pre-use validation checks, and staff training on manual override procedures are non-negotiable prerequisites for clinical adoption.[14]

- **Equity, Access, and Global Health Disparities:**

The advanced robotic systems described in this review have been developed predominantly in well-resourced academic centres in high-income countries. Their high acquisition and maintenance costs, combined with the need for reliable infrastructure, trained technical support, and uninterrupted power supply, risk widening the already significant gap between high-income and low-to-middle-income healthcare settings. Furthermore, AI algorithms trained largely on data from specific patient populations

may perform less reliably when applied to populations with different physiological profiles, genetic backgrounds, or disease burdens. For robotic anaesthesia to fulfil its promise of improving patient safety globally, its development must be underpinned by a commitment to algorithmic diversity, affordable hardware design, and implementation strategies tailored to resource-constrained environments.[41]

- **Regulatory Pathways and Clinical Validation:**

AI-based medical devices occupy a uniquely challenging regulatory space. Unlike traditional pharmaceutical agents or medical devices with static performance profiles, machine learning algorithms can evolve with new data, meaning that a system approved at one point in time may behave differently after software updates or retraining. Regulatory bodies such as the United States Food and Drug Administration (FDA) and the European Medicines Agency (EMA) are actively developing frameworks for "adaptive AI" devices, but international consensus remains incomplete.[7] In the perioperative context, rigorous multicentre randomised controlled trials are still lacking many of the systems described in this review. Before widespread clinical application, the field requires prospective outcome data across diverse patient populations, standardised performance benchmarks, and transparent post-market surveillance protocols to ensure that approved systems continue to perform safely in real-world practice.[42]

1.8 Conclusions

As medicine progresses towards future, the operating theatre will undoubtedly undergo a major technological evolution. The vision of the future features an environment free of manual paperwork, where wireless sensors deliver real-time patient data to AI networks, while pharmacological and mechanical robots seamlessly induce patients to anaesthesia, keep them stable, and ensure safe emergence.

However, robotic anaesthesia is not a sign that anaesthesiologists will be replaced. By taking over the repetitive, tiring, complex tasks of anaesthetic care, robotics refines the role of the anaesthesiologist from a manual operator of anaesthetic care to high-level perioperative physician and systems supervisor. Ultimately, the future of anaesthesia relies on human-machine collaboration. The consistent accuracy and massive data-processing power of robots are perfectly balanced by the clinical judgment, ethical oversight, and crisis-management skills of the anaesthesiologists. This evolution will set an unprecedented standard for anaesthesia and ensuring the highest levels of patients' safety.

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Protein, Energy, and Outcomes in Critically Ill Patients: What Anaesthesiologists Need to Know

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Abstract

Optimal (nutritional) therapy in critically ill patients remains a topic of ongoing debate, particularly regarding the appropriate dosing of protein and energy during the early phase of critical illness. While artificial nutrition is a standard component of intensive care management, determining the optimal macronutrient prescription is challenging. Current international guidelines provide heterogeneous recommendations for protein and energy delivery, reflecting uncertainty in the evidence base.

Over the past decade, several large randomised controlled trials have evaluated the clinical effects of higher versus lower protein and energy delivery in critically ill patients. Four major trials examining protein dosing, including EFFORT Protein, PRECISE, TARGET Protein, and the study by O’Keefe and colleagues, consistently demonstrated that early higher protein provision does not improve clinical outcomes compared to lower protein delivery during the first week up to 10 days of critical illness. In some subgroups, particularly patients with more severe illness or greater organ dysfunction, higher early protein delivery was associated with worse clinical outcomes. Similarly, four landmark trials evaluating energy dosing, namely EDEN, PermiT, TARGET Energy, and NUTRIREA-3, compared various caloric strategies during the early phase of critical illness. Across these studies, higher energy delivery initiated early after intensive care unit (ICU) admission did not improve mortality or other major clinical outcomes and was frequently associated with poorer gastrointestinal tolerance or metabolic complications.

Collectively, these trials suggest that aggressive early nutrition strategies might overwhelm the metabolic capacity of critically ill patients, particularly during periods of haemodynamic instability or severe organ failure. Consequently, a progressive and individualised approach to nutritional therapy is recommended. Early nutrition should be initiated at low or maintenance doses during the acute phase of illness, with gradual escalation as physiological stability improves during the stabilization phase and as patients transition toward recovery. Continuous assessment of metabolic tolerance is essential to guide adjustments in protein and energy delivery. This phase-adapted feeding strategy aligns nutrient provision with the evolving metabolic state in critical illness and may help minimise the risks of both overfeeding and underfeeding.

Keywords: Protein, Energy, Clinical Nutrition, Intensive Care Medicine

2.1 Introduction

Nutrition is a fundamental pillar of human physiology, yet its application in the intensive care unit (ICU) remains one of the most debated aspects of critical care. Consequently, the initiation of artificial nutrition support is a standard component of care for ICU patients. However, the seemingly simple task of “feeding” the critically ill patient belies a complex clinical challenge: determining the precise prescription of protein and energy.

Current clinical guidelines provide varying recommendations on optimal protein intake for critically ill patients. The 2022 guidelines from the American Society for Parenteral and Enteral Nutrition (ASPEN) recommend a relatively broad protein target of 1.2–2.0 g/kg/day [1]. In contrast, the 2023 practical and partially revised European Society for Clinical Nutrition and Metabolism (ESPEN) guideline suggests a progressive approach, targeting approximately 1.3 g/kg/day [2]. More recently, the French 2025 guidelines have proposed a substantially lower protein strategy during the early phase of critical illness, recommending 0.2–0.9 g/kg/day (adjusted for body mass index, BMI) during the first week in mechanically ventilated patients [3].

Similarly, recommendations for energy delivery vary across international guidelines. The ASPEN 2022 guideline suggests providing approximately 12–25 kcal/kg/day during the first 7–10 days of ICU stay.[1] The ESPEN 2023 guideline recommends that isocaloric nutrition be gradually introduced after the early phase of acute illness, starting around day 3 when indirect calorimetry is available. When predictive equations are used to estimate energy requirements, hypocaloric feeding—generally defined as less than 70% of estimated needs—is recommended during the first week of ICU admission.[2] In contrast, the French 2025 guidelines advocate for a much lower energy provision of 6–8 kcal/kg/day (adjusted for BMI) during the first week in mechanically ventilated patients.[3]

These notable discrepancies among major guidelines raise important clinical questions regarding the optimal prescription of protein and energy for critically ill patients. Over the past decade, several large and methodologically rigorous randomised controlled trials have evaluated the effects of higher versus lower protein or energy delivery on clinically relevant outcomes. Understanding the design, implementation, and results of these landmark trials is essential for clinicians, including anaesthesiologists involved in perioperative and critical care management, to interpret the evidence and make informed decisions regarding nutritional therapy in the ICU.

2.2 Landmark Trials investigating Protein Dosing in Critically Ill Patients

Between 2023 and 2025, the landscape of critical care nutrition was fundamentally reshaped by four large-scale randomised controlled trials (RCTs): the EFFORT Protein trial, the PRECISE trial, the TARGET Protein trial, and the trial by O’Keefe et al.

2.2.1 EFFORT Protein Trial

The EFFORT Protein trial was a multicentre, parallel –group, open-label, pragmatic, registry-based randomised trial that enrolled 1,301 adult mechanically ventilated patients with high nutritional risk from 85 ICUs across 15 countries.[4] High nutritional risk was defined by the presence of at least one of the following: malnutrition according to local assessment, risk of sarcopenia, pre-ICU frailty, BMI ≤ 25 kg/m² or ≥ 35 kg/m², or an anticipated duration of mechanical ventilation exceeding four days. Within 96 hours of ICU admission, patients were randomised to receive either high protein (target ≥ 2.2 g/kg/day) or usual protein (target ≤ 1.2 g/kg/day) for up to 28 days during the ICU stay.

The intervention commenced at a median of approximately 39 hours after ICU admission and lasted about 10 days. Median protein delivery was 1.7 (interquartile range [IQR] 1.3–2.0) g/kg/day in the high-protein group and 1.0 (IQR 0.8–1.1) g/kg/day in the usual-protein group, while mean energy delivery was similar between groups (14.7 $\pm$ 6.9 vs 13.2 $\pm$ 6.4 kcal/kg/day).

The primary outcome, defined as the cumulative incidence of alive hospital discharge by day 60, showed no statistically significant difference between groups (hazard ratio [HR], 0.91; 95% confidence interval [CI] 0.77 to 1.07; $p=0.27$). Likewise, 60-day mortality did not differ significantly (risk ratio [RR] 1.08, 95% CI 0.92 to 1.26). Subgroup analyses suggested potential harm associated with higher protein delivery among patients with greater number or severity of organ failure. Specifically, patients with acute kidney injury (AKI) at admission who received higher protein had longer times to discharge alive and higher 60-day mortality compared with those without AKI. Similarly, patients with a Sequential Organ Failure Assessment (SOFA) score ≥ 9 experienced a slower time to discharge alive when assigned to higher protein. Blood urea levels were significantly higher in the high-protein group. Post hoc analyses further demonstrated that higher versus lower protein delivery did not improve clinical outcomes in patients at high nutritional risk (defined by modified Nutrition Risk in Critically Ill [NUTRIC] score 5–9), those classified as malnourished according to Global Leadership Initiative on Malnutrition (GLIM) or modified Academy/ ASPEN Indicators of Malnutrition criteria, or in patients with obesity (BMI

≥ 30 kg/m²).[5, 6]

2.2.2 PRECISE Trial

The PRECISE trial was a double-blind, parallel-group RCT conducted across five hospitals in the Netherlands and five in Belgium, enrolling 935 mechanically ventilated patients without contraindications to enteral nutrition.[7] Patients were randomised to receive enteral nutrition providing either 2.0 g/kg/day or 1.3 g/kg/day of protein. Protein delivery was gradually increased by 25% each day until reaching the full target intake by day 4, and the intervention continued for up to 90 days in the ICU.

The intervention began approximately one day after ICU admission and lasted about nine days on average. Median protein delivery was 1.87 (IQR 0.96-2.00) g/kg/day in the high-protein group and 1.19 (IQR 0.63-1.26) g/kg/day in the lower-protein group, while mean energy delivery was identical between groups (19.0 $\pm$ 9.0 kcal/kg/day).

The primary outcome was health-related quality of life, measured using the EQ-5D-5L health utility score at 30, 90, and 180 days after randomisation, adjusted for baseline values. In this scoring system, death is assigned a score of zero, integrating mortality and quality of life into a composite measure. The study found that the EQ-5D-5L health utility score was significantly lower in the high-protein group (mean difference -0.05; 95% CI -0.10 to -0.01; $p=0.031$), and this effect remained after adjustment for baseline Acute Physiology and Chronic Health Evaluation II (APACHE II) score, sex, admission diagnosis, and Nutrition Risk Screening (NRS-2002) score.

In the high protein group, the point estimates of the adjusted analysis suggest a concerning trend of increased mortality up to day 180 (HR 1.24, 95% CI 0.99 to 1.55; $p=0.063$). Additionally, gastrointestinal intolerance occurred more frequently in the high-protein group (odds ratio [OR] 1.76, 95% CI 1.06 to 2.92; $p=0.030$). Subgroup analyses showed that the negative effect on EQ-5D-5L health utility scores was particularly evident among female patients and those admitted with medical diagnoses, while mortality appeared higher among patients with medical admissions who received higher protein.

2.2.3 TARGET Protein Trial

The TARGET Protein trial was a cluster-randomised, crossover, open-label study conducted across eight ICUs in Australia and New Zealand.[8] Each ICU alternated between two treatment strategies –augmented protein versus usual protein –for three-month periods over a 12-month study duration. The trial enrolled 3,397 adult patients aged 16 years or older who were prescribed enteral nutrition. Patients received isocaloric enteral formulas differing in protein content (100 g/L vs 63 g/L) for up to 90 days in the ICU. Feeding rates were determined according to usual clinical practice but were

capped at 1 mL/kg of ideal body weight per hour.

The intervention began approximately 19 hours after ICU admission and lasted a median of around 3.5 days. Median protein delivery was 1.12 (IQR 0.71-1.53) g/kg ideal body weight/day in the augmented-protein group and 0.69 (IQR 0.40-0.95) g/kg ideal body weight/day in the usual-protein group, while median energy delivery was similar between groups (14 [IQR 9-19] vs 14 [IQR 8-19] kcal/kg ideal body weight/day).

The primary outcome, days alive and free of the index hospital by day 90, did not differ significantly between groups (adjusted median difference -1.97 days; 95% CI -7.24 to 3.30; $p=0.46$). Secondary clinical outcomes were also similar. However, blood urea concentrations on day 10 were significantly higher in the augmented-protein group. Subgroup analyses suggested possible heterogeneity of treatment effect, with signals of harm associated with augmented protein among patients receiving mechanical ventilation (very low credibility) and those receiving new renal replacement therapy at baseline (moderate credibility).

2.2.4 O’Keefe et al.

Finally, O’Keefe and colleagues conducted a single-centre, parallel-group RCT involving 500 mechanically ventilated trauma and surgical patients with an expected ICU stay of more than seven days.[9] Participants were randomised to receive early enteral protein supplementation along with standard enteral nutrition or standard enteral nutrition alone.

The intervention was initiated within 72 hours of ICU admission and lasted up to 28 days. During the first seven days, the mean protein delivery was approximately 1.2 g/kg/day in the intervention group compared with 0.6 g/kg/day in the control group. Because the protein supplement also provided additional energy, total energy delivery was higher in the intervention group.

The primary outcome, serum transthyretin concentration, did not differ significantly between groups. The study was also designed to evaluate 28-day ventilator-free days, which were similarly not different between groups. However, patients receiving higher protein experienced significantly higher rates of reintubation and diarrhoea.

2.3 Landmark Trials investigating Energy Dosing in Critically Ill Patients

Several large and robust RCTs have examined the effects of different energy delivery strategies in critically ill patients. They are the EDEN, PermiT, TARGET Energy, and NUTRIREA-3 trials, which together provide important evidence informing contemporary recommendations on energy dosing in the ICU.

2.3.1 EDEN 2012

EDEN was a multicentre, open-label, RCT conducted across 44 hospitals in the United States.[10] A total of 1,000 adults with acute lung injury requiring mechanical ventilation were enrolled within 48 hours of diagnosis when clinicians intended to initiate enteral nutrition. Patients were randomised to receive either trophic feeding or full enteral feeding during the first six days of mechanical ventilation; thereafter, patients who remained ventilated in both groups received full feeding.

More than 90% of participants were randomised within 48 hours of intubation. During the first six days, patients in the full-feeding group received approximately 1,300 kcal/day (about 80% of their calculated energy goals), while those in the trophic-feeding group received approximately 400 kcal/day (about 25% of their calculated energy goals), corresponding to approximately 14.9 versus 4.7 kcal/kg/day.

The primary outcome, ventilator-free days at day 28, showed no significant difference between groups (risk difference [RD] -0.1; 95% CI -1.4 to 1.2; $p=0.89$). Similarly, 60-day mortality did not differ significantly (RD 1.0%; 95% CI -4.1% to 6.3%; $p=0.77$). Gastrointestinal intolerance, including regurgitation, vomiting, elevated gastric residual volumes, and constipation, occurred less frequently in the trophic-feeding group. During the intervention period, the full-feeding group also had higher mean plasma glucose levels and required greater insulin administration. No significant interactions were observed in prespecified subgroup analyses.

At the one-year follow-up, survivors from both groups showed similar outcomes in physical function, cognitive performance, quality of life, psychosocial measures, fatigue, and employment status, indicating no long-term benefit of early full feeding compared with trophic feeding.[11, 12]

2.3.2 PermiT 2015

PermiT was a multicentre, open-label, pragmatic RCTs conducted in seven centres in Saudi Arabia and Canada.[13] The study enrolled 894 patients who received enteral nutrition within 48 hours of ICU admission and were not receiving high-dose vasopressors. Participants were randomised to permissive underfeeding (targeting 40-60% of calculated energy requirements) or standard feeding (targeting 70-100% of calculated energy requirements) for up to 14 days in the ICU. Protein targets were set at 1.2-1.5 g/kg/day in both groups.

Randomisation occurred approximately eight hours after eligibility confirmation, and the mean intervention duration was about nine days. The average total energy delivery, including calories from propofol, intravenous dextrose, and parenteral nutrition, was 1299 ± 467

kcal/day ($71 \pm 22\%$ of estimated requirements) in the standard-feeding group and 835 ± 297 kcal/day ($46 \pm 14\%$) in the permissive-underfeeding group, corresponding to approximately 16.0 ± 5.8 versus 10.6 ± 3.8 kcal/kg/day. Protein delivery was similar between groups: 59 ± 25 ($69 \pm 25\%$) versus 57 ± 24 ($68 \pm 24\%$) g/day, corresponding to approximately 0.73 ± 0.31 versus 0.72 ± 0.30 g/kg/day.

The primary outcome, 90-day mortality, showed no significant difference between groups (RR 0.94; 95% CI 0.76 to 1.16; $p=0.58$). Secondary outcomes, including ICU length of stay and infection rates, were also similar. However, the incidence of renal replacement therapy was higher in the standard-feeding group compared with the permissive-underfeeding group (RR 0.63; 95% CI 0.40 to 0.98; $p=0.04$). Prespecified subgroup analyses revealed no significant interactions.

Post hoc analyses further confirmed that nutritional risk, as defined by the NUTRIC score, did not influence the relationship between permissive underfeeding or standard feeding and 90-day mortality.[14]

2.3.3 TARGET Energy 2018

TARGET Energy was a multicentre, double-blind, RCTs involving 46 ICUs in Australia and New Zealand ICUs.[15] A total of 3,957 mechanically ventilated adult patients requiring enteral nutrition were randomized to receive either an energy-dense enteral formula (1.5 kcal/mL) or a routine formula (1.0 kcal/mL). Both were administered at a standardized rate of 1 mL/kg of ideal body weight per hour (capped at 100 mL/hour), beginning within 12 hours of initiation of nutritional support and continuing for up to 28 days in the ICU.

The intervention began approximately 16 hours after ICU admission and lasted a median of six days (IQR 3 -11 days) in the ICU. Mean total energy delivery, including calories from propofol, dextrose, citrate, and parenteral nutrition, was 1930 ± 547 kcal/day in the energy-dense group compared with 1407 ± 397 kcal/day in the routine-formula group, corresponding to 30.2 ± 7.5 versus 21.9 ± 5.6 kcal/kg ideal body weight/day. Protein delivery (from trial nutrition only) was similar between groups: 69.6 ± 17.8 versus 69.4 ± 17.2 , or 1.09 ± 0.22 versus 1.08 ± 0.23 g/kg ideal body weight/day.

The primary outcome, 90-day mortality, did not differ significantly between groups (risk ratio 1.05; 95% CI 0.94 -1.16; $p=0.41$). Secondary outcomes, including organ support requirements and infection rates, were also comparable. However, patients on the energy-dense formula experienced more episodes of high gastric residual volumes, regurgitation or vomiting, and required more prokinetic medications. They also had higher daily blood glucose levels and greater insulin requirements. No significant treatment effects were observed across prespecified subgroups.

At the six-month follow up, mortality was similar between groups. Among survivors, quality of life

measured using the EQ-5D-5L instrument, and employment outcomes remained similar between groups.[16]

2.3.4 NUTRIREA-3 2023

NUTRIREA-3 was a multicentre, open-label, pragmatic RCT conducted across 61 ICUs in France. The study enrolled 3,044 mechanically ventilated adults receiving vasopressor support for shock. Participants were randomised within 24 hours of intubation to receive either a low energy and protein strategy (6 kcal/kg/day with 0.2–0.4 g/kg/day of protein) or a standard energy and protein strategy (25 kcal/kg/day with 1.0–1.3 g/kg/day of protein) during the first seven days of ICU stay. At baseline, patients were severely ill, receiving a median norepinephrine-equivalent dose of 0.50 (IQR 0.25–1.00) µg/kg/min.

The intervention started approximately 17 hours after intubation. During the intervention period, median energy delivery including calories from propofol, dextrose, and parenteral nutrition was 22.0 (IQR 17.5–24.9) kcal/kg/day in the standard energy and protein group and 7.4 (IQR 5.8–9.5) kcal/kg/day in the low energy and protein group. Median protein delivery was 0.9 (IQR 0.7–1.0) versus 0.2 (IQR 0.2–0.3) g/kg/day, respectively.

The trial had two primary outcomes. Ninety-day mortality was not significantly different between the groups (risk difference –1.5%; 95% CI –5.0% to 2.0%; $p=0.41$). However, patients receiving the standard energy and protein approach took longer to be ready for ICU discharge compared to those on the low energy and protein approach (hazard ratio 1.12; 95% CI 1.02–1.22; $p=0.015$). Secondary outcomes also indicated poorer tolerance with the standard energy and protein approach, including longer mechanical ventilation duration, higher rates of ICU infection, and increased gastrointestinal complications such as vomiting and diarrhoea. In addition, bowel ischemia and liver dysfunction occurred more frequently in the standard energy and protein group.

2.4 Summary of the trial results

Taken together, eight large and methodologically robust RCTs—four evaluating protein dosing and four evaluating energy dosing provide important insights for nutritional management in critically ill patients (Table 2.1 and Table 2.2). Across diverse ICU populations, these trials consistently demonstrated that higher energy or protein provision, initiated early after ICU admission (approximately 8–72 hours) and continued for about 7–10 days, did not improve clinically relevant outcomes. These findings challenge the long-held assumption that early aggressive nutritional therapy improves recovery during the acute phase of critical illness.

Evidence from the aforementioned large protein RCTs

indicates that early administration of higher protein doses (≥ 1.2 g/kg/day), initiated approximately 19–39 hours after ICU admission and continued for about 4 to 10 days, does not confer clinical benefits compared with lower protein provision of approximately 0.7 to <1.2 g/kg/day. Subgroup analyses from these trials also suggest potential harm in certain patient populations. In particular, patients with more severe illness, reflected by a greater degree of organ dysfunction such as a SOFA score ≥ 9 , the presence of AKI, or the requirement for mechanical ventilation, appeared to have worse outcomes when exposed to early higher protein doses. Similar signals of harm were observed in specific subgroups, including patients admitted with medical diagnoses and female patients.

Similarly, the four large RCTs mentioned earlier, which evaluated energy dosing, compared various energy delivery strategies. These included trophic versus moderate feeding,[10] trophic versus full feeding,[17] permissive underfeeding versus standard feeding,[13] and lower versus higher full-energy strategies.[15] Despite these comparative differences between groups, initiating higher energy provision early, within approximately 8–72 hours after ICU admission and continuing during the first week of illness, did not improve clinical outcomes. Instead, higher energy delivery was often associated with poorer gastrointestinal tolerance, metabolic disturbances, or worse clinical outcomes. These negative effects appeared to be more evident in patients with greater severity of illness or more extensive organ dysfunction.

2.5 Recommendations for Clinical Practice

The observation of worse clinical, gastrointestinal, or metabolic outcomes with higher early macronutrient delivery—particularly among severely ill patients—likely reflects the underlying physiological limitations during the acute phase of critical illness. During periods of profound metabolic stress and organ dysfunction, the body's capacity to effectively utilise exogenous nutrients may be impaired.[18, 19] Excessive macronutrient provision during this phase may therefore increase metabolic burden and place additional stress on already compromised organs. Consequently, early high-dose nutrition should generally be avoided in patients with severe illness or multiple organ failure. Importantly, these considerations appear to supersede baseline nutritional status;[20, 5] even patients at higher nutritional risk or with pre-existing malnutrition, early high-dose nutrition during the acute unstable phase of critical illness may not be advisable. Conversely, prolonged and severe underfeeding in stabilised patients—for example, beyond one to two weeks—may also be detrimental.

Given the dynamic and evolving metabolic state of critically ill patients, nutritional therapy should adopt

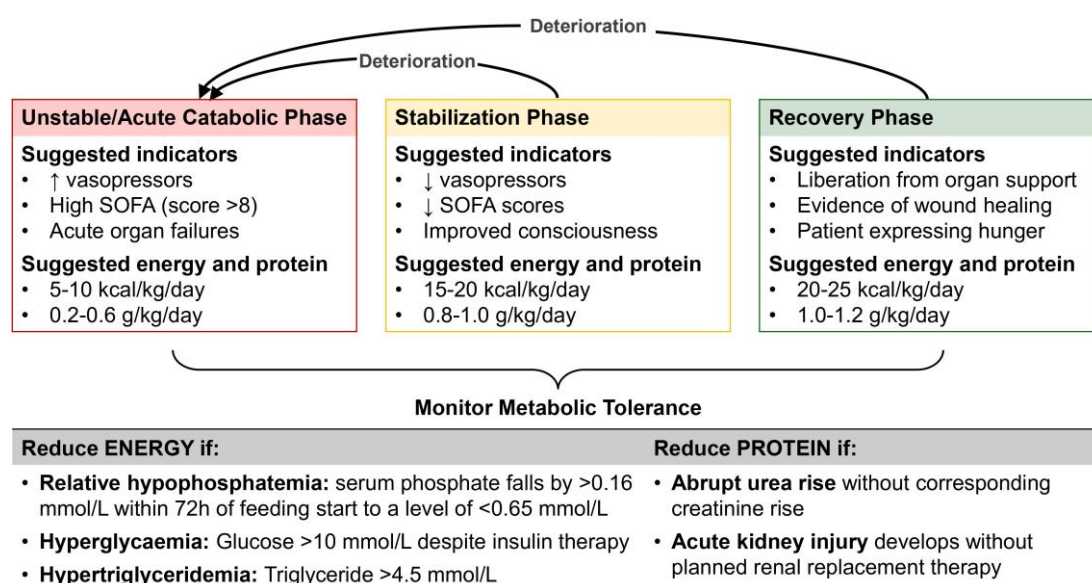


Figure 2.1: Phase-Adapted Feeding Strategy. Deterioration is defined as rising vasopressor needs or worsening organ dysfunction. Abbreviation: SOFA, Sequential Organ Failure Assessment. Adapted from: Stoppe C, Lee ZY, Arabi YM. Nutritional therapy and a stepwise approach in critical illness: aligning provision with metabolic phases. *Curr Opin Clin Nutr Metab Care.* 2026;29(2):184–92.

a progressive and individualised approach guided by the patient's clinical trajectory rather than relying solely on the number of days spent in the ICU.[21] A phase-adapted feeding strategy has been proposed in which nutritional delivery is gradually escalated as physiological stability improves.[22] In this framework, nutrition is initiated cautiously during the acute, unstable phase and advanced stepwise as the patient transitions toward stabilisation and recovery phase. Such an approach aligns nutritional provision with the patient's clinical trajectory and metabolic capacity, and may reduce the risk of both overfeeding and underfeeding (Figure 2.1).

During the early unstable or acute catabolic phase –often characterized by escalating vasopressor requirements, new organ failures, or persistently high or rising SOFA scores –nutritional support should be limited to maintenance levels. This may correspond to approximately 5–10 kcal/kg/day of energy and 0.2–0.6 g/kg/day of protein until clinical stabilisation is achieved. As patients improve and enter a stabilisation phase, indicated by declining vasopressor requirements, decreasing SOFA scores, improved consciousness, and the initiation of mobilisation, nutritional delivery can be progressively increased over several days to approximately 15–20 kcal/kg/day and 0.8–1.0 g/kg/day of protein. During the recovery phase –marked by liberation from organ support, evidence of wound healing, and in some patients who express hunger –nutritional support can be further escalated to approximately 20–25 kcal/kg/day and 1.0–1.2 g/kg/day of protein. At any stage of the ICU course, deterioration in clinical status should prompt reassessment and de-escalation of nutritional delivery

back to maintenance levels.

Because metabolic tolerance varies substantially among individuals, ongoing monitoring is essential during each phase of critical illness. Indicators of metabolic intolerance should prompt adjustments to nutritional therapy. Energy delivery may need to be reduced in the presence of relative hypophosphatemia (a decline in serum phosphate greater than 0.16 mmol/L within 72 hours of initiating nutrition support to a level below 0.65 mmol/L),[23] uncontrolled hyperglycaemia (blood glucose >10 mmol/L) despite appropriate insulin therapy,[24] or hypertriglyceridaemia (triglyceride levels >4.5 mmol/L).[25] Similarly, protein provision may be reduced when serum urea increases abruptly without a corresponding rise in creatinine,[26] or when AKI develops in the absence of planned renal replacement therapy.[27]

Overall, these data support a cautious, individualised, and physiologically guided approach to nutritional therapy in critically ill patients. Rather than prioritising early achievement of high energy or protein targets, clinicians should focus on aligning nutrient delivery with the patient's metabolic capacity and evolving clinical condition.

2.6 Conclusion

Recent large and robust RCTs have consistently demonstrated that early high energy and protein doses are not beneficial and can be harmful to critically ill patients, particularly those with greater illness severity and organ failure. Feeding should generally be initiated with low energy and protein doses and

advanced progressively while monitoring the clinical status and metabolic tolerance of individual patients.

Table 2.1: Summary of landmark randomised controlled trials evaluating protein doses in critically ill patients

Protein RCTs	EFFORT Protein 2023 ⁴	PRECISE 2024 ⁷	TARGET Protein 2025 ⁸ (clustered RCT)	O’Keefe et al 2025 ⁹
Population (n)	Mechanically ventilated – expected MV ≥48 h, high nutrition risk (n=1301)	Mechanically ventilated ≤24 h – expected MV ≥3 d, EN-fed (n=935)	EN-fed (n=3397)	Mechanically ventilated trauma/surgical, expected ICU stay 7 d (n=500)
Intervention timing^a				
Start	~39 h of ICU admission	~1 d of ICU admission	~19 h of ICU admission	≤72 h of ICU admission
Duration	~10 d in the ICU	~9 d in the ICU	~3.5 d in the ICU	while receiving EN in ICU
Nutrition delivery^b				
Protein, g/kg	1.7 [1.3–2.0] vs 1.0 [0.8–1.1]	1.87 [0.96–2.0] vs 1.19 [0.63–1.26]	1.12 [0.71–1.53] vs 0.69 [0.40–0.95]	1.2±0.65 vs 0.6±0.39 over first 7 ICU days
Energy, kcal/kg	14.7±6.9 vs 13.2±6.4	19.0±9.0 vs 19.0±9.0	14.0 [9.0–19.0] vs 14.0 [8.0–19.0]	Higher in high protein group
Primary Outcome(s)	TTDA from hospital by day 60: ↔	EQ-5D-5L health utility score: ↓ (worsen)	Days free of index hospital and alive by day 90: ↔	Transthyretin on days 14–21: ↔
Unfavourable outcomes	• AKI: ↑ 60-day TTDA, ↑ mortality • SOFA ≥9: ↑ 60-day TTDA	• Female: ↓ EQ-5D-5L • Medical: ↓ EQ-5D-5L, ↑ overall mortality	Mechanically ventilated and receiving new RRT: worse primary outcome	↑ reintubation, diarrhoea, blood urea nitrogen up to week 2
Favourable outcome	Nil	Nil	Nil	Nil

AKI, acute kidney injury; EN, enteral nutrition; EQ-5D-5L, EuroQol 5-Dimension 5-Level; ICU, intensive care unit; MV, mechanical ventilation; RCT, randomized controlled trial; RRT, renal replacement therapy; SOFA, Sequential Organ Failure Assessment; TTDA, time to discharge alive Note: Data are presented as mean ± SD or median [IQR]; Outcome direction: ↔, no significant difference; ↓ / ↑, decreased/increased in intervention group

^aActual timing shown where reported; protocol-defined timing when unavailable – O’Keefe et al 2025

^bNutrition delivery reflects daily energy and protein delivered during the intervention period, unless otherwise stated.

Table 2.2: Summary of landmark randomised controlled trials evaluating energy doses in critically ill patients

Energy RCTs	EDEN 2012 ¹⁰	PermiT 2015 ¹³	TARGET Energy 2018 ¹⁵	NUTRIREA-3 2023 ¹⁷
Population (n)	Acute lung injury on MV <72h, EN-fed (n=1000)	96.8% on MV, no high-dose vasopressors, EN-fed (n=894)	Mechanically ventilated, EN-fed (n=3957)	Mechanically ventilated, high-dose vasopressor(0.5 ug/kg/min) (n=3036)
Intervention timing^a				
Start	≤ 72h of MV	~8 h of ICU admission	~16 h of ICU admission	~17h of MV
Duration	Up to 6 d of MV	~9 d in the ICU	6 [3-11] d in ICU	Up to 7 d of MV
Nutrition delivery^b				
Energy, kcal/kg	~14.9 vs 4.7*	~16.0±5.8 vs 10.6±3.8*	30.2±7.5 vs 21.9±5.6	22.0 [17.5-24.9] vs 7.4 [5.8-9.5]
Protein, g/kg	Not reported	~0.73±0.31 vs 0.72±0.30*	1.09±0.22 vs 1.08±0.23	0.9 [0.7-1.0] vs 0.2 [0.2-0.3]
Primary Outcome(s)	28-d ventilator-free days: ↔	90-d mortality: ↔	90-d mortality: ↔	• 90-d mortality: ↔ • Time-to-readiness for ICU discharge: ↑
Unfavourable outcomes	• ↑ GI intolerance: GRV, regurgitation, vomiting, constipation • ↑ blood glucose level, insulin	↑ incidence of renal replacement therapy	• ↑ GI intolerance: GRV, regurgitation/vomiting, prokinetic therapy • ↑ blood glucose level, insulin	• ↑ GI intolerance: vomiting, diarrhoea, bowel ischemia, liver dysfunction • ↑ time-to-MV weaning • trend ↑ ICU mortality, infection
Favourable outcome	Nil	Nil	Nil	Nil

EN, enteral nutrition; GI, gastrointestinal; GRV, gastric residual volume; ICU, intensive care unit; MV, mechanical ventilation.

Note: Data are presented as mean ± SD or median [IQR]. Outcome direction: ↔, no significant difference; ↑, increased in intervention group

^aActual timing shown where reported; protocol-defined timing when unavailable – EDEN 2012, NUTRIREA-3 2023 (duration)

^bNutrition delivery reflects daily energy and protein delivered during the intervention period.

*estimated by dividing with the reported mean weight

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Surgeon Perspective on Patient Safety: Views from the Other Side of the Divide

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Abstract

“A good surgeon must have an eagle’s eye, a lion’s heart, and a lady’s hand”, so says an old English proverb. Surgery does not involve only technicality, but the surgical outcome is very much dependent on the safety of the patient. A safe procedure ensures a good outcome. There is surely no use of a good anastomosis or a fixed bone, in a dead patient. Hence, looking at a patient’s safety is of utmost importance!”

3.1 What Is Patient Safety?

What is patient safety though? The Ministry of Health of Malaysia states that it is the prevention of errors and adverse effects to patients associated with health care.[1] The World Health Organization (WHO) states that it is the absence of preventable harm to a patient and reduction of unnecessary harm associated with health care to an acceptable minimum.[2] Within the broader health system context, it is a framework of organized activities that creates cultures, processes, procedures, behaviours, technologies and environments in health care that consistently and sustainably lower risks, reduce the occurrence of avoidable harm, make error less likely and reduce impact of harm when it does occur. WHO also states that approximately 1 in 10 patients is harmed while receiving hospital care, and more than 50% of this harm is preventable.

This raises two critical questions: what affects patient safety, and who should be responsible for it?

3.2 A Multidisciplinary Team Approach

When it comes to management of a patient, more often than not, we think of it as a single person, a single team or a single specialty effort. However, it is my view that it is of multiple heads or specialties that need to come together to ensure that a patient's safety is upheld. Two heads is indeed better than one, what more multiple heads! We do believe that understanding other specialties' concerns, especially when it involves patient safety is vital and should not be taken lightly. We must not merely brush it aside due to inconvenience or consider it a burden to be carried out. Multiple teams may inevitably act as a security net, to ensure correct processes are followed with the patient's safety in mind.

The majority of the time, the patient is encountered most frequently by the surgical teams. Potentially, there are decisions that are best agreed upon with the other managing teams, as the surgeon's view may have its own blind spots. From the preoperative period, the decision for surgery is usually assessed and determined by the surgeon. There are certain cases where resectability of a tumour is borderline, and a tumour board meeting or a multidisciplinary discussion is important to have joint consensus, before embarking on high-risk surgeries. Subsequently, if the tumour is resectable, it should be ensured that the patient is truly fit and optimized for surgery. This is typically done via another type of multi-disciplinary approach, like enhanced recovery after surgery (ERAS) or the perioperative medicine team. Typically, ERAS is a collaboration between surgeons, anaesthesiologists, physicians, physiotherapists, dieticians, pharmacists and perhaps, in the future, psychologists. Some may think, why are so many counterparts involved to ensure one surgery goes well? It is true that while some roles

may overlap, no one can truly master all areas. In complex patients, a multi prong approach is best to bring the patient's condition to an optimum. Truly, an optimized patient is a safe patient.

3.3 Availability of Protocols, Morbidity and Mortality Meetings and Audit

Each institution should also ensure protocols are set in place. Protocols like "Safe Surgery Saves Lives" are one of the many examples that each hospital should adopt. Mechanisms like audits and morbidity and mortality meetings must take place so that mistakes are not repeated. These meetings should be carried out as a fact-finding exercise and not a witch hunt, to encourage many to learn and improve their clinical practice. Careful considerations to invest in certain equipment and technology must be considered by each institution to further elevate learning and patient safety, while balancing out the cost factor. Good governance will yield good safety measures, which will in turn enhance value-based healthcare.

3.4 Mechanisms to Audit Surgical Capabilities

However, all this will also only be a success story, if the surgeon takes a deep introspection on their capabilities to operate. Knowing when to cut and when to stop is of paramount importance. As the adage goes, "A good surgeon knows how to operate, a better surgeon when to operate, and the best surgeon when not to operate". All surgeons need to select patients appropriately according to their personal capability and the support systems available. This is particularly easy to mention, but it is never easy to be carried out, as many have different ways of auditing their clinical work and outcome, as well as understanding their full capabilities. The selection of patients may be easy to execute in bigger centres with a wider network of skilled personnel. It is my personal opinion that at the very least the presence of a visiting mentor may be of value in keeping track of complex surgical outcomes and providing valuable input. With new technology, it is easier to record procedures be it open or minimally invasive. This serves as a tool to audit practices and at the same time to augment the learning curve.

3.5 Availability of Tools for Learning

Furthermore, another safety perspective of the surgeon is getting the technique right. This is commonly done by practice. After all, it is practice that yields perfection. Previously, it was under the guidance of a supervisor that a surgeon would learn and get his

craft right on a patient. With current cutting-edge technologies, there are many tools for practice in the market that can help enhance procedural skills. Some of these tools can be self-purchased, but the more sophisticated ones should be bought, serviced and maintained by each institution. We can no longer rely on the use of patients solely as an experience mill. The various methods of learning and improving a skillset has to be incorporated to ensure patient safety.

3.6 Conclusion

At the end of the day, patients' safety is not just the responsibility of a sole individual. The mindset and the culture of healthcare practitioners need to be formed correctly. Perhaps, our biggest frustration is when we observe that a clinician may inadvertently choose to act individualistically. When we work in silo, we may very well end up working against each other. For many years as a trainee, and even as a junior surgeon, I shared several differences with others when we attempted to execute a new plan. In retrospect, there were many needed discussions to understand each person's perspective.

We must all remember that everything we do is to ensure the patient's best outcome. If the patient's care and outcome is the end goal, and all stakeholders share the same vision, surely, we can all work towards this goal. It is my continued hope that we uphold patient advocacy as we continue to treat our patients.

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Awake Deep Brain Stimulation Surgery: Anaesthetic Considerations and Clinical Practice

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KEY POINTS

- Main anaesthetic concerns during awake deep brain stimulation procedure are a restricted-access difficult airway from the fixed stereotactic frame, Parkinson's respiratory and autonomic dysfunction, limited patient cooperation, and tight blood-pressure control (systolic <140 mmHg) to prevent haemorrhage.
- Surgery is done in two stages—awake lead placement under monitored anaesthesia care, then pulse-generator implantation under general anaesthesia—with device programming beginning 2–4 weeks post-operatively.

4.1 Introduction to Deep Brain Stimulation (DBS)

Deep Brain Stimulation (DBS) is a sophisticated neurosurgical intervention involving the implantation of a medical device to modulate abnormal neural activity. Often described as a “pacemaker for the brain,” the procedure utilizes thin electrodes implanted into specific subcortical structures. These electrodes deliver controlled electrical impulses that regulate the dysfunctional signalling responsible for various movement and neurological disorders. A standard DBS system comprises three primary components: the lead (electrode) targeted at a specific nucleus, an extension wire tunnelled subcutaneously, and a battery-powered implantable pulse generator (IPG) which acts as the system’s power source. While recent evidence suggests that deep brain stimulation (DBS) under general anaesthesia (GA) yields equivalent clinical benefits[1, 2], awake DBS has traditionally been regarded as the gold standard. The awake approach provides immediate physiological feedback on stimulation, which is particularly critical in surgical environments lacking intraoperative CT (iCT) or MRI (iMRI) capabilities.[3, 4]

4.2 Indications and Clinical Targets

DBS is primarily indicated for the symptomatic management of Parkinson’s disease, essential tremor, and dystonia. However, emerging evidence supports its expanding role in selected cases of epilepsy, obsessive-compulsive disorder, and other neuropsychiatric conditions. Local anaesthesia is traditionally used in DBS implantation for these disorders because it allows for a more reliable MER to locate the target nucleus.[5]

It is important to note that while DBS significantly alleviates symptoms, it is not a curative treatment for the underlying disease process. Target selection is dictated by the specific pathology; the subthalamic nucleus (STN) and globus pallidus internus (GPi) are common targets for Parkinson’s disease, while the ventral intermediate nucleus (VIM) of the thalamus is preferred for essential tremors. Successful intervention typically results in reduced motor fluctuations, decreased dyskinesia, a significant reduction in pharmacological requirements, and a marked improvement in the patient’s overall quality of life.

4.3 Preoperative Evaluation

Candidates for DBS must undergo a rigorous evaluation by a multidisciplinary team, including a movement disorder neurologist, a functional neurosurgeon, a neuro-anaesthetist, and a neuropsychologist. The

primary objectives are to confirm the diagnosis, optimize medical management, and assess surgical and anaesthetic risks. Screening for cognitive impairment, dementia, and psychiatric comorbidities is mandatory. Furthermore, comprehensive patient counselling is essential to manage expectations regarding the device’s benefits, potential complications, and the necessity of long-term follow-up.

4.4 Specific Considerations

4.4.1 Airway Assessment and Consideration

The significant concern during Stage 1 of the procedure is the potential for a difficult airway. Because the patient’s head is immobilized in a rigid stereotactic frame, this “restricted access” poses a grave risk should an emergent airway crisis arise while the patient is under conscious sedation.[6]

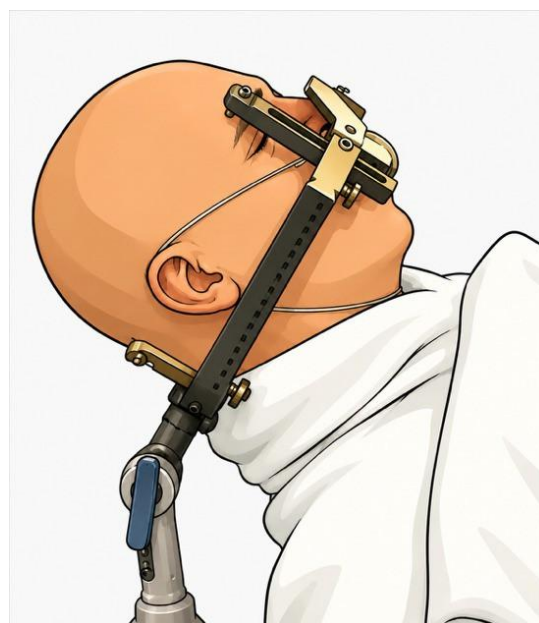


Figure 4.1: This picture demonstrates head immobilization using a rigid stereotactic frame, which restricts access to the patient’s airway. Note that nasal cannula oxygen is routinely applied before the frame is attached. The head is usually elevated approximately 30 degrees in a semi-sitting position.

4.4.2 Physiological Manifestations of Parkinson’s Disease

- **Respiratory & Bulbar Dysfunction:** Impaired respiratory reserve, sleep apnoea, and poor cough or swallowing reflexes (bulbar palsy) significantly increase the risk of aspiration and post-operative pulmonary complications.
- **Autonomic Instability:** Dysregulation of the autonomic nervous system may lead to orthostatic hypotension or thermoregulatory issues, such as hypothermia.

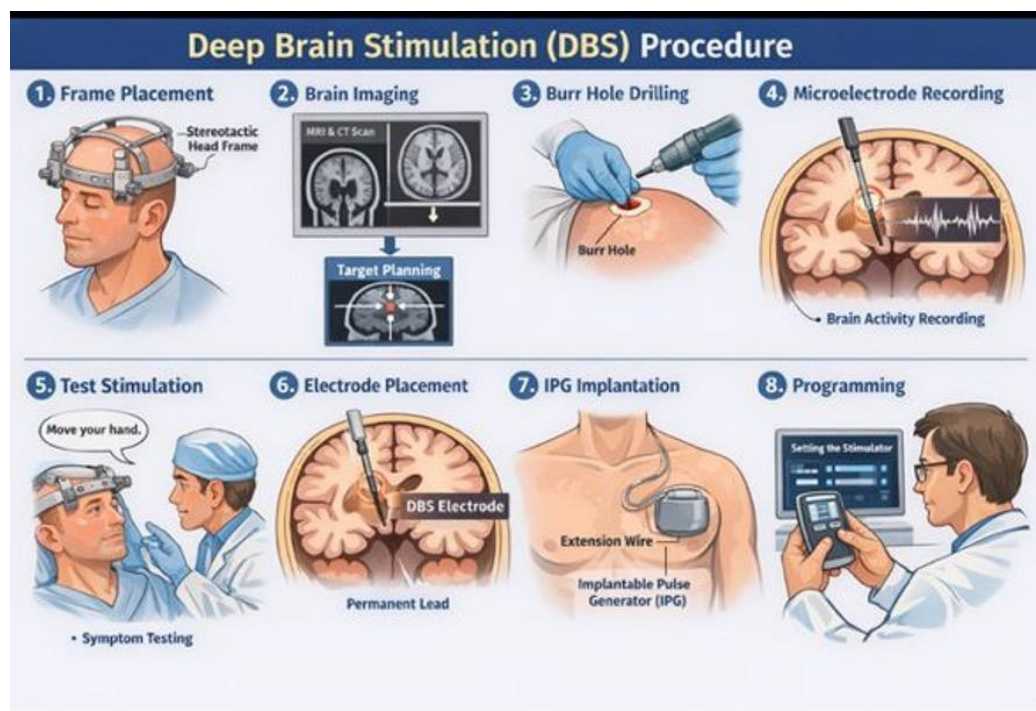


Figure 4.2: Summary of steps during deep brain stimulation procedure.

- **Musculoskeletal & Nutritional Status:** Skeletal deformities, chronic malnourishment and tremors can make positioning difficult.[6]

4.4.3 Cognitive and Behavioural Challenges

The “awake” nature of the procedure requires a high degree of patient cooperation. However, many candidates face cognitive challenges, including varying degrees of dementia, behavioural abnormalities, and communication difficulties. These factors can make it difficult for the patient to tolerate the prolonged immobilization of the frame or the stress of intraoperative neurological testing.[6]

4.4.4 Hemodynamic Control

Uncontrolled hypertension significantly increases the risk of a catastrophic intracerebral haemorrhage as the microelectrodes or permanent leads pass through the brain parenchyma. Tight hemodynamic control keeping systolic blood pressure within a narrow, pre-determined range is vital to ensure a bloodless and safe surgical corridor. A systolic blood pressure of <140 mmHg or within 20% of patient normal range is targeted.[6, 7, 8]

4.5 Anaesthetic and Surgical Technique

The surgical procedure is typically conducted in two distinct stages:

Stage 1: Lead Placement (Awake): To facilitate intraoperative clinical testing, the first stage is

generally performed while the patient is awake. After the application of a stereotactic head frame—often supplemented by a scalp block[9] and light sedation (e.g. propofol, dexmedetomidine and remifentanyl)—the patient undergoes CT imaging for coordinate mapping (X, Y, Z axes). A burr hole is then created, and microelectrode recording (MER) is used to identify the characteristic firing patterns of the target nuclei. Temporary stimulation allows the team to assess clinical improvement in rigidity and tremors while monitoring for adverse effects such as paraesthesia or speech disturbances. Once the optimal position is confirmed, the permanent lead is anchored to the skull. During this stage, an airway trolley is kept readily available, with a supraglottic airway (SGA) prepared as the primary option for airway rescue in case of emergency.

Monitored anaesthesia care (MAC) during awake stage: can be done with or without processed EEG guidance (e.g. BIS index aiming 40–60) with the following agents:

- **Propofol:** May be administered in target controlled infusion (TCI), either as a sole agent or in combination with short acting opioid (e.g. fentanyl or remifentanyl). Propofol acts on GABA receptors but induces only minor alteration to STN discharge activity.[5, 6] It offers advantages of rapid onset offset of action, however it can precipitate hemodynamic instability, respiratory depression particularly when co-administered with opioid and may cause disinhibition accompanied by confusion.
- **Dexmedetomidine:** This is the preferred agent in many institutions as it has no effect on GABA

receptors and mimics natural sleep via activation of alpha-2 adrenoreceptors in locus coeruleus. Low dose infusion induces anxiolysis and provides easily arousable sedation, with no effect on MER.[5, 6] It also attenuates hemodynamic responses to surgical stimulation. However, a loading dose should be avoided as dexmedetomidine can cause initial hypertension.

Stage 2: IPG Implantation (General Anaesthesia): In the second stage, the patient is placed under general anaesthesia. The extension wires are tunnelled under the skin from the cranium to the chest wall, where they are connected to the IPG.

4.6 Possible Complications

- Respiratory complication including hypoventilation, airway obstruction, aspiration due to oversedation, intracranial events, upper airway secretion or Parkinson's disease related complication.[6]
- Cardiovascular complication including hypertension due to anxiety, agitation or procedure itself. It could also be hypotension due to autonomic dysfunction, hypovolemia or anaesthetic induced vasodilatation.[6, 7]
- Venous air embolism risk is increased due to semi sitting position and hypovolemia.[6]
- Neurological complications including seizures, intracranial haemorrhage, delirium and rarely pneumocephalus.[6, 10]

4.7 Postoperative Care and Considerations

Device programming typically commences two to four weeks post-surgery. Using an external controller, clinicians adjust the voltage, frequency, and pulse width to achieve optimal symptom control. Patients must be informed of potential surgical risks, including intracranial haemorrhage, infection, or seizures. Furthermore, lifestyle adjustments—such as precautions regarding MRI compatibility, airport security scanners, and specific physical activities—must be thoroughly discussed to ensure the long-term integrity of the hardware.

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Building a Future-Ready Vascular Anaesthesia Service in Malaysia

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Abstract

Malaysia's transition into an ageing society, together with a rising prevalence of diabetes, chronic kidney disease, peripheral arterial disease, and tobacco-related vascular pathology, has translated into a measurable and growing burden of vascular surgical disease. These patients frequently present with advanced systemic atherosclerosis, frailty and significant cardiac, renal and cerebrovascular comorbidities. These categorised them at high risk of perioperative myocardial injury, stroke, acute kidney injury, major haemorrhage and markedly elevated one-year mortality. Concurrently, vascular surgical activity is expanding, with increasing volumes of open surgery combined with the complexity of hybrid and endovascular interventions.

The next phase of vascular care in Malaysia is to ensure that the entire perioperative system can consistently support increasingly complex procedures, particularly when patients are frail, operations are prolonged, complications occur suddenly and immediate rescue is required. Although Malaysia has skilled anaesthesiologists and substantial experience within major tertiary vascular centres, expertise in vascular anaesthesia remains largely acquired through local exposure and individual experience. Thus, a structured vascular anaesthesia training pathway could establish defined competencies and improve service delivery in the perioperative management of vascular surgical patients. Proposed training domains include advanced cardiovascular assessment and haemodynamic management, patient blood management, organ-protection strategies, one-lung ventilation, regional anaesthesia and crisis management during vascular rupture, reperfusion injury or conversion to open surgery.

This article is a call for a stronger perioperative partnership between anaesthesiology, vascular surgeons, intensivists, hospital leadership and other relevant disciplines. Well established hybrid operating theatres, advanced monitoring, cell salvage, point-of-care coagulation testing and massive transfusion systems should therefore be developed as integrated components of the vascular anaesthesia service framework. Provision models must also recognise the realities of vascular care in Malaysia, including time-sensitive surgery, referrals across large geographical distances, limited opportunities for preoperative optimisation and financial constraints affecting access to endovascular treatment.

Keywords: Vascular Anaesthesia, Malaysia, Endovascular, Vascular Surgery, Collaboration

5.1 Introduction

The proportion of adults aged 65 and above in Malaysia has increased from approximately 3.1% in 1970 to around 7.7% of the total population in 2024. This marks Malaysia's transition into an ageing society according to United Nations criteria.[1] This demographic shift is of concern as it is accompanied by a rising burden of non-communicable diseases, including diabetes mellitus, chronic kidney disease, peripheral arterial disease (PAD), and obesity, alongside modifiable lifestyle factors such as smoking and vaping.[2, 3]

In this regard, population-based studies in Asia demonstrate a measurable burden of abdominal aortic aneurysm (AAA). A meta-analysis of screening studies reported an AAA prevalence of 1.3% (95% CI 0.9–1.8%) in general populations, increasing to 2.6% among individuals with cardiovascular risk factors.[4] Local surgical data reflect that this burden translates into substantial operative demand. Over a five-year period, 496 abdominal aortic surgeries were performed at Hospital Kuala Lumpur (HKL), of which 451 cases (90.9%) involved AAA.[5] Open repair remained the predominant technique (395 cases, 87.5%), while endovascular aneurysm repair (EVAR) was performed in 36 patients (8.0%).[5]

Thus, this article offers an initial perspective on the broader vision for structured vascular anaesthesia service and training in Malaysia, with the current challenges in vascular anaesthesia. It does not attempt to cover every operational, funding, governance, or workforce issue in full. Instead, it focuses on selected service gaps and training needs that may serve as a starting point for further discussion and future service development perspectives.

5.2 Evolution of Vascular Surgery in Malaysia

Hospital Kuala Lumpur began formal vascular surgery training in the 1990s and has since played a central role in developing the vascular surgical workforce across Malaysia.[5] Over time, training capacity has expanded to major tertiary hospitals across Peninsular Malaysia and East Malaysia. The growth of vascular services is reflected in procedural volume.[5, 6] Institutional audit data from HKL recorded approximately 700 vascular and 460 endovascular procedures in 2024.[6] In 2025, the total number of vascular procedures increased to 903 vascular surgery cases and 660 endovascular interventions.[6]

Vascular surgery has undergone a significant transformation, evolving from a field dominated by open surgical reconstruction into one increasingly defined by complex endovascular and hybrid interventions. In the Malaysian public healthcare setting, the availability of EVAR is strongly influenced by funding and graft procurement. Endovascular

stent grafts remain costly, and access may be limited by institutional budget allocation, procurement processes, and case prioritisation. Additionally, several comparator health systems have more established public reimbursement or national insurance mechanisms for selected EVAR/TEVAR devices and procedures.[7]

Patients undergoing vascular surgery represent one of the most physiologically vulnerable groups encountered in perioperative medicine. These patients frequently have advanced systemic atherosclerosis and a high prevalence of cardiovascular comorbidities, contributing to increased perioperative morbidity and mortality. A prospective cohort of 2,641 vascular surgery patients reported that 24% developed myocardial injury after non-cardiac surgery and 8.8% experienced myocardial infarction within one year with significant associated mortality.[8] Postoperative myocardial infarction following vascular surgery has been associated with approximately 37% mortality at one year compared with 5% among patients without myocardial infarction.[9]

Vascular anaesthesia must address multiple physiological challenges during the management of surgical emergencies such as aortic dissection, ruptured aneurysm, acute and chronic limb ischaemia, mesenteric ischaemia and acute vascular injury. Open vascular procedures often involve rapid haemodynamic changes during aortic clamping and declamping, while endovascular interventions may require controlled hypotension during stent deployment with the need for a hybrid OT for rapid transition to open surgery for combined or acute complications of the endovascular procedure. Furthermore, complex thoracoabdominal surgery may involve one-lung ventilation, major blood loss, and prolonged operative duration while also posing risks of spinal cord ischaemia, stroke, and reperfusion injury.[9, 10]

These advances have expanded treatment options for patients with aortic disease, carotid pathology, and PAD, while simultaneously increasing the physiological and logistical complexity of perioperative care. Having said that, as surgical capability advances across Malaysia, anaesthesia services must evolve alongside this to ensure that the safety and resilience of perioperative management of high-risk non-cardiac surgery keep pace with procedural innovation. Within this context, the development of vascular anaesthesia services represents a natural progression in the maturation of perioperative medicine.

5.3 Infrastructure and Monitoring Requirements

Contemporary practice increasingly relies on sophisticated monitoring tools that allow more precise assessment of cardiovascular physiology and earlier detection of haemodynamic instability.

Technologies such as advanced haemodynamic monitoring systems, including FloTrac or Vigileo and the Hypotension Prediction Index (HPI), cerebral oximetry, perioperative echocardiography and point-of-care ultrasound provide clinicians with real-time physiological insights that support more targeted and individualised haemodynamic management for high-risk non-cardiac surgery patients. Therefore, these play a crucial role in guiding fluid resuscitation, assessing cardiac performance, and ensuring timely haemodynamic stabilisation during episodes of massive bleeding and reperfusion injury. Reperfusion following aortic cross-clamping or revascularisation may precipitate distributive shock, while patients with significant underlying cardiovascular disease may develop cardiogenic shock during periods of physiological stress.

Transoesophageal echocardiography (TOE) has also become increasingly valuable during complex endovascular aortic procedures such as thoracic endovascular aortic repair (TEVAR).[9] Beyond its traditional role in cardiac assessment, TOE allows real-time visualisation of the thoracic aorta and can assist in tracking the position of guidewires and endovascular devices during the procedure. In experienced hands, TOE may help identify the guidewire tip's location within the true lumen and facilitate more precise positioning before endovascular graft deployment. This contributes to more accurate graft landing and may reduce the risk of malposition or inadvertent coverage of major aortic branches. In addition, perioperative TOE enables early detection of important procedural complications such as new aortic dissection, malposition of the graft, pericardial effusion or ventricular dysfunction. In this setting, TOE can provide real-time information on ventricular filling, biventricular function, regional wall motion abnormality, valvular pathology, pericardial pathology, and possible causes of unexplained haemodynamic instability.[11] These capabilities further highlight the expanding role of perioperative echocardiography as an important adjunct in the anaesthetic management of complex vascular and endovascular procedures. Ideally, other methods of patient monitoring such as PAC and emerging strategies such as near-infrared spectroscopy for spinal cord perfusion monitoring and renal biomarkers for early detection of acute kidney injury may become increasingly relevant, although their implementation should be guided by local availability, appropriate expertise, and evidence-based protocols.

Management of major vascular surgery frequently requires coordinated patient blood management (PBM) strategies. Efforts in strengthening the first pillar of PBM through aggressive identification and treatment of preoperative conditions should begin in the primary clinic despite time-sensitive surgery. Many elective and semi-urgent patients would benefit from earlier investigation of anaemia, iron deficiency, renal-related anaemia, antiplatelet and anticoagulant issues, and

transfusion planning. This also includes the activation of structured massive transfusion protocols (MTP), utilisation of point-of-care coagulation monitoring, and implementation of blood conservation techniques aligned with the pillars of PBM. Strategies such as intraoperative cell salvage and acute normovolaemic haemodilution play an important role in reducing allogeneic transfusion requirements during complex vascular procedures.

Organ protection strategies remain central to the safe conduct of high-risk vascular surgery. Effective perioperative management requires careful anticipation of ischaemia–reperfusion injury and the implementation of targeted protective strategies. These include cerebral protection and monitoring, such as cerebral oximetry during carotid and aortic arch procedures, spinal cord protection during thoracoabdominal aortic repair with external lumbar drainage and optimisation of renal and visceral perfusion during prolonged periods of aortic or carotid artery cross-clamping.

5.4 Development of Hybrid Operating Theatre Capability

Modern vascular surgery progressively relies on complex perioperative infrastructure, especially in high-volume vascular centres. The integration and development of hybrid operating theatres (OT) represent one of the most significant technological shifts, comprising advanced endovascular imaging systems with the capability to convert immediately to open surgery. However, hybrid OT environments introduce unique anaesthetic challenges and workflow. Endovascular navigation may be prolonged for up to 8 to 12 hours, requiring sustained haemodynamic precision rather than intermittent correction during extended image-guided manipulation of the vasculature.

Other challenges include line placement strategies, airway contingency planning, radiation safety considerations, and monitor visibility, all of which must be redesigned around imaging equipment and sterile fluoroscopic zones. The use of high contrast volumes necessitates renal protection strategies, particularly in patients with pre-existing renal impairment. Additionally, any endovascular procedure carries the possibility of sudden conversion to open surgery, requiring immediate readiness of the managing teams for major haemorrhage, escalation of monitoring and haemodynamic support. Therefore, major vascular centres would benefit from standardised hybrid OT design frameworks incorporating durable high-performance image intensifiers capable of prolonged use and an integrated advanced haemodynamic monitoring system. Thus, without coordinated planning, hybrid theatres risk becoming radiology suites with anaesthesia added later, rather than fully integrated perioperative

environments.

5.5 Service and Workforce Capacity

High-risk vascular surgery benefits from the concentration of medical expertise. International models often organise complex vascular procedures within designated regional centres with experienced multidisciplinary teams. A coordinated combined clinic involving vascular surgeons, anaesthesiologists, and other relevant specialities allows more efficient patient assessment, streamlined decision-making, and timely risk mitigation prior to surgery. Such structured exposure would also strengthen collaboration between anaesthesiologists, vascular surgeons, and critical care teams. While vascular anaesthesia training may contribute to developing expertise within the public sector, long-term retention requires wider institutional and government-level strategies beyond the scope of this article.

The establishment of combined multidisciplinary clinics or multidisciplinary discussion teams has become increasingly important in vascular surgery services. Patients are frequently referred from across the country to tertiary vascular centres, which limits the feasibility of traditional separate preoperative assessments conducted by different specialities. In addition, many vascular conditions are time-sensitive and require urgent intervention, further constraining the window available for extensive preoperative investigations and stabilisation strategies.

Completing this effort, the development of clear institutional guidelines, local and national protocols, is a way forward, particularly within major training centres where frequent rotation of trainees and staff may introduce variability in practice. Standardised protocols for procedures such as external lumbar drainage, MTP, renal protection and blood conservation strategies help ensure consistent and safe anaesthesia care delivery. Structured algorithms addressing complications such as cerebral hyperperfusion syndrome and systemic reperfusion injury are equally important.

In addition, standardisation of preoperative assessment and risk optimisation pathways can further enhance high-risk non-cardiac surgery perioperative risk stratification and multidisciplinary planning for complex vascular surgical patients.[12] Cardiopulmonary exercise testing (CPET) can provide an objective assessment of functional capacity and perioperative physiological reserve. Similarly, cardiac stress investigations such as exercise stress testing or pharmacological stress testing, including dobutamine stress echocardiography, may help to detect occult myocardial ischaemia and guide perioperative risk stratification and optimisation strategies.[13]

5.6 Structured Vascular Anaesthesia Competency Pathway

Internationally, vascular anaesthesia is recognised as a focused area of advanced perioperative training and professional development through dedicated fellowship pathways and specialist vascular anaesthesia societies (Fiona Stanley Fremantle Hospitals Group, 2025; University of Ottawa, n.d.; Vascular Anaesthesia Society of Great Britain and Ireland, n.d.). In the United Kingdom, major vascular surgery is centralised within regional vascular centres supported by consultant anaesthesiologists experienced in vascular anaesthesia and multidisciplinary perioperative services. National guidance from the Royal College of Anaesthetists and the Vascular Society emphasises consultant-led care, advanced monitoring, and structured perioperative pathways for vascular patients.[14] Australia, New Zealand, and Canada also provide a nationally coordinated specialist training programme with rotational exposure to vascular surgery and subspecialty development through dedicated special interest groups.[15, 16] Many tertiary academic hospitals provide advanced fellowships in vascular anaesthesia and high-risk non-cardiac surgery supported by hybrid operating theatres, perioperative echocardiography, and collaborative research networks aimed at improving perioperative outcomes.[16]

At present, vascular anaesthesia expertise in Malaysia is largely experience-based rather than structured. Many anaesthesiologists develop proficiency through exposure in tertiary centres such as HKL and other high-volume institutions, but a clearly defined competency pathway has yet to be formally established. In response to this need, the Ministry of Health Malaysia has begun to explore the development of subspecialty or area-of-interest training in vascular anaesthesia within anaesthesia and critical care. Ongoing efforts are defining the scope of training, competency domains, and service requirements necessary to support the development of a structured vascular anaesthesia pathway. The aim would not necessarily be to create a separate speciality but to ensure that anaesthesiologists managing high-risk vascular cases acquire consistent competencies.

A proposed one-year area-of-interest training programme could aim to produce anaesthesiologists with advanced knowledge and skills in vascular anaesthesia and perioperative vascular medicine. Key domains could include advanced haemodynamic monitoring, perioperative echocardiography, spinal cord protection strategies in aortic surgery, brain protective strategies for carotid surgery, and crisis management during sudden vascular rupture or conversion from endovascular to open surgery. Training also includes expertise in point-of-care coagulation testing and patient blood management, visceral perfusion assessment, one-lung ventilation for

thoracoabdominal surgery and regional anaesthesia.

Malaysia may therefore benefit from the continued development of regional high-volume vascular centres supported by trained anaesthesia teams familiar with complex endovascular and open aortic procedures, as well as other complicated vascular surgeries. Such centres can also function as hubs for training, research, and guideline development.

5.7 Data, Audit, and Outcome Tracking

Malaysia has made strong progress in subspecialty vascular anaesthesia training and service delivery.[6, 7] However, national data on perioperative vascular surgery and anaesthesia remain limited. Establishing structured audit systems could provide valuable insight into outcomes of vascular surgery and anaesthesia in the Malaysian context. This may include monitoring rates of myocardial injury after non-cardiac surgery, stroke after carotid procedures, spinal cord injury following thoracoabdominal repair, and transfusion practices in major vascular operations and centres. Reliable national data would support evidence-based planning and protocol, workforce development, and quality improvement initiatives.

Audit initiatives could be coordinated by national professional bodies, such as the Malaysian Society of Anaesthesiologists and the College of Anaesthesia of Malaysia (MSACoA), in collaboration with vascular surgical societies and academic centres. Professional organisations can also play an important role in facilitating these conversations, encouraging training opportunities, and supporting initiatives that build national capacity in vascular anaesthesia. Therefore, this article suggests a collaboration among Ministry of Health hospitals, university hospitals, and, where appropriate, private-sector partners for coordinated national capacity building. In this context, the development of vascular anaesthesia should be viewed as part of national vascular service planning, rather than as an isolated anaesthesia initiative.

5.8 Conclusion

Major aortic and complex endovascular procedures demand specialised perioperative expertise, advanced monitoring capabilities, and coordinated multidisciplinary care. Through continued collaboration between anaesthesiologists, vascular surgeons, intensivists, and hospital leadership, Malaysia can progressively build a more resilient and future-ready vascular anaesthesia service capable of supporting the growing complexity of vascular surgical and perioperative care in the coming decades.

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Same Day Admission for Elective Lower Segment Caesarean Section: A Quality Improvement Initiative in Obstetric Anaesthesia at Universiti Malaya Medical Centre (UMMC)

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Abstract

Same Day Admission (SDA) for elective lower segment caesarean section (LSCS) is an important component of Enhanced Recovery After Caesarean (ERAC) pathways but has not been widely implemented in Malaysia. In March 2025, Universiti Malaya Medical Centre (UMMC) introduced a structured SDA programme as a quality improvement initiative to optimise resource utilisation while maintaining patient safety and experience.

A prospective quality improvement project incorporating clinical audit principles was conducted among carefully selected low-risk (ASA II) parturients undergoing elective LSCS. The pathway included preoperative assessment in the Obstetric Anaesthesia Clinic, standardised counselling, outpatient investigations, multidisciplinary coordination, ERAC-based perioperative care, and continuous monitoring of maternal and neonatal outcomes, readmissions, length of stay, patient recovery using the ObsQoR-11 questionnaire, and financial impact.

Between March 2025 and February 2026, 128 women underwent elective LSCS through the SDA pathway. The average hospital stay was reduced to approximately three days, with no observed increase in maternal or neonatal complications or hospital readmissions. The initiative generated an estimated saving of RM530 per patient, amounting to cumulative savings of RM67,840. Patients reported high satisfaction with the efficient admission processes, shorter hospitalisation, and greater convenience. Median ObsQoR-11 scores ranged from 7 to 9 across all domains, indicating favourable postoperative recovery, adequate pain control, functional independence, and positive psychological recovery. Successful implementation relied on multidisciplinary collaboration, standardised protocols, staff engagement, and continuous audit to overcome operational challenges.

This pilot quality improvement initiative suggests that SDA for elective LSCS is feasible and can be implemented safely in carefully selected patients. The early experience at UMMC indicates that a structured ERAC-based SDA pathway has the potential to improve operational efficiency while maintaining favourable maternal and neonatal outcomes. Further evaluation with a larger cohort and longer follow-up is warranted to confirm these findings and inform wider implementation in Malaysian obstetric centres.

Learning Points

- A structured SDA pathway may safely reduce preoperative hospitalisation for carefully selected women undergoing elective LSCS without adversely affecting maternal or neonatal outcomes.
- Multidisciplinary collaboration, standardised preoperative assessment, and continuous quality audit are essential for successful implementation and sustainability of this pathway.
- SDA is consistent with ERAC principles and has the potential to improve patient experience, optimise bed utilisation, and reduce healthcare costs in tertiary obstetric centres.

Keywords: Caesarean Section; Enhanced Recovery After Caesarean; Patient Satisfaction; Same Day Admission; Quality Improvement

6.1 Introduction

Elective Lower Segment Caesarean Section (LSCS) has traditionally required hospital admission at least one day prior to surgery. While this conventional practice allows for logistical convenience and patient readiness, it is frequently associated with longer hospital stay, increased bed occupancy, higher institutional costs, and greater exposure to nosocomial infections. In high-volume obstetric centres, these challenges are further magnified by rising LSCS rates and increasing demands on limited healthcare resources.

In response to these pressures and in line with the shift in global practices towards Enhanced Recovery After Surgery (ERAS)[1] and Enhanced Recovery After Caesarean (ERAC)[2] protocols, the Obstetric Anaesthesia and Obstetric Unit at Universiti Malaya Medical Centre (UMMC) initiated a structured Quality Improvement (QI) project in March 2025 to implement Same Day Admission (SDA) for carefully selected elective LSCS patients. This initiative represented a transition from routine early admissions to a protocol-driven, patient-centred perioperative pathway designed to reduce length of hospital stay, promote early mobilisation, and improve postoperative outcomes.

Since its inception, the SDA Project has demonstrated safety, feasibility, cost-effectiveness, and high patient satisfaction. In recognition of its impact, the project was awarded the Anugerah Khas Projek Inovasi & Penambahbaikan Kualiti 2025, Pusat Perubatan Universiti Malaya, affirming its institutional value and sustainability.

6.2 Background and Rationale

The conventional practice of admitting elective LSCS patients one day prior to surgery was justified by the need for preoperative investigations, anaesthetic evaluation, and logistical preparation. However, with the establishment of structured preoperative obstetric anaesthesia clinics and improved perioperative protocols, many of these processes can now be done safely in the outpatient setting, thereby minimising unnecessary hospitalisation.

Same Day Admission has already been successfully implemented across multiple surgical disciplines including general surgery, orthopaedics, gynaecology, dental procedures, and otorhinolaryngology, with favourable outcomes. However, the application of SDA specifically to elective LSCS has been less widely explored, and while SDA has been adopted for elective LSCS in several healthcare systems internationally, published data regarding its safety and feasibility remain relatively limited. Furthermore, there is currently no published data on the implementation of SDA for elective LSCS in Malaysia.

Hence, with the growing interest in ERAS and ERAC protocols and their demonstrated positive outcomes,[3,

4] together with the successful adoption of SDA in other surgical specialties, there has been increasing interest in exploring its safe application in obstetric surgery. The benefits of SDA include reduced length of hospital stay, improved bed turnover, lower healthcare expenditure, decreased exposure to hospital-acquired infections, and enhanced patient autonomy and satisfaction.

At UMMC, increasing LSCS census and bed occupancy prompted a re-evaluation of preoperative admission practices. Even a modest reduction in inpatient days could translate into substantial cumulative institutional savings and improved system efficiency.

The introduction of SDA is therefore aligned with three key strategic goals:

- Enhancing patient-centred care
- Optimising hospital resource utilisation
- Supporting value-based healthcare delivery

6.3 Project Objectives

The primary aim of this initiative is to evaluate the feasibility, safety, cost-effectiveness, and patient satisfaction associated with SDA for elective LSCS at UMMC.

The specific objectives include optimising bed utilisation and departmental workflow, assessing maternal and neonatal outcomes under the SDA pathway, evaluating patient recovery using validated tools such as ObsQoR-11,[5] identifying implementation barriers and operational challenges, and analysing financial implications for the institution.

During the early implementation phase, inclusion criteria were deliberately restricted to low-risk elective LSCS patients (ASA II) to prioritise patient safety.

6.4 Quality Improvement Methodology

This initiative was designed as a prospective observational study and clinical audit, incorporating structured QI principles. Continuous monitoring included maternal complications, neonatal outcomes, scheduling efficiency, recovery metrics, readmission rates, length of stay, and patient satisfaction.

The project emphasised governance, multidisciplinary engagement, and continuous data review to ensure sustainability and safety.

6.5 Implementation Strategy

6.5.1 Preoperative Phase

Patients scheduled for elective LSCS attend the Obstetric Anaesthesia Clinic one day prior to surgery.

During this visit:

- Blood investigations are taken
- Anaesthetic evaluation is conducted (effective outpatient preoperative assessment is crucial to ensure that patients meet the eligibility criteria for SDA)
- Consent is obtained
- ERAC pathway counselling is provided
- Fasting instructions and admission logistics are clarified

This structured preoperative clinic became the cornerstone of the SDA pathway, ensuring patients are optimised and well-informed before surgery.

6.5.2 Day of Surgery

Patients arrive 2–4 hours prior to the scheduled surgery. Cardiotocography (CTG) is performed in the antenatal ward, with confirmation of GSH prior to proceeding for surgery as scheduled.

Clear communication between Obstetrics, Anaesthesiology, Nursing, and administrative staff ensures minimal delay and seamless patient flow.

6.5.3 Postoperative Care

Standard monitoring protocol, multimodal analgesia, early mobilisation and oral intake, and discharge within 24–48 hours when clinically appropriate, in accordance with ERAC protocols.

6.6 Early Outcomes

From March 2025 until February 2026, a total of 128 patients underwent elective LSCS through the SDA

pathway.

The results showed:

- The average hospital stay has been reduced to approximately three days
- No significant increase in maternal or neonatal complications was reported
- No significant increase in readmission rates

These findings demonstrate that SDA can be safely implemented within a structured ERAC framework when applied to appropriately selected patients.

6.7 Financial Impact

Table 6.1 compares traditional preoperative admission costs with the SDA pathway.

This translates to a saving of approximately RM530 per patient. With 128 patients recruited to date, the cumulative estimated savings amount to RM67,840.

In a centre with high annual elective LSCS volume, reducing even one inpatient day per patient translates into substantial institutional savings annually. Beyond direct financial benefits, SDA also contributes to improved bed availability, reduced administrative burden, enhanced operating theatre scheduling efficiency and better patient flow within obstetric services.

Table 6.1: Comparing Traditional Preoperative Admission Costs with SDA Pathway

Institutional Costs	Traditional Practice	SDA Pathway
Preoperative hospital stay	RM 300	RM 0
Nursing care (pre-op)	RM 150	RM 0
Meals (pre-op day)	RM 50	RM 0
Housekeeping	RM 30	RM 0
Administrative costs	RM 100	RM 100
Total estimated cost per patient	RM 630	RM 100

6.8 Patient Experience & Satisfaction

While financial and operational outcomes are important, the most compelling aspect of this initiative has been patient experience. Feedback from patients consistently stated efficient admission processes, reduced waiting times, shorter hospital stay, and greater convenience and autonomy.

One patient described her experience as smoother, more

controlled, and significantly less stressful compared to her previous Caesarean delivery under conventional admission. The ability to attend a family event the day before surgery and return home earlier postpartum illustrates the patient-centred advantage of SDA. Such testimonials reinforce the importance of combining clinical safety with compassionate, efficient care.

Preliminary ObsQoR-11 assessments demonstrate good maternal recovery scores within 24 hours postoperatively, reinforcing the alignment between

SDA and enhanced recovery principles.

Table 6.2 represents the median score for each item of the postoperative recovery scale (ObsQoR-11). Overall, median scores ranged from 7.00 to 9.00, indicating an overall positive postoperative recovery experience. The two items with the highest median scores were “severe pain” (9.00), and “have been comfortable” (9.00). It is important to note that items related to symptoms such as pain and shivering are negatively worded; therefore, higher scores reflect lower symptom severity. This suggests that most patients did not experience severe pain and felt comfortable postoperatively.

Functional recovery domains, including mobilisation, infant care, and personal hygiene, showed consistently high median scores (8.00), indicating that patients were able to perform daily activities independently. The domain “feeling in control” also achieved a high median score (8.00), reflecting positive psychological recovery and patient confidence following surgery. Overall, recovery remained favourable. These findings suggest that parturients undergoing SDA for LSCS generally experience good postoperative recovery with adequate pain control and functional independence.

Table 6.2: Median Scores of Postoperative Recovery Scores (ObsQoR-11) for Same Day Admission

ObsQoR-11 item	Median (IQR)
Moderate pain	7.00 (3.25–9.00)
Severe pain	9.00 (6.25–10.00)
Nausea or vomiting	7.00 (3.00–9.75)
Feeling dizzy	8.00 (4.25–10.00)
Shivering	8.00 (4.00–9.00)
Have been comfortable	9.00 (5.25–10.00)
Able to mobilise independently	8.00 (5.00–10.00)
Can hold baby without assistance	8.00 (5.50–9.00)
Can feed/nurse baby without assistance	8.00 (5.25–9.00)
Can look after personal hygiene/toilet	8.00 (6.25–9.00)
Feeling in control	8.00 (7.00–9.00)

6.9 Challenges and Lessons Learned

Despite its success, implementation requires significant interdepartmental coordination. Key challenges included workflow adjustment among nursing and administrative teams, aligning theatre scheduling, managing patient anxiety regarding same-day admission, and ensuring clear communication pathways. The solution to this includes regular multidisciplinary meetings, continuous strong interdepartmental collaboration, ensuring clear communication protocols/Standard Operating Procedure, staff education, structured patient selection criteria and continuous audit and monitoring.

6.10 Institutional Recognition

In 2025, this initiative was awarded the Anugerah Khas Projek Inovasi & Penambahbaikan Kualiti, PPUM. This award recognises its innovation, multidisciplinary collaboration, and measurable institutional impact.

6.11 Broader Implications and National Relevance

The SDA pathway aligns with ERAC principles, with a possibility of a value-based healthcare, national cost-containment strategies, and optimisation of tertiary hospital bed capacity. It represents a possible scalable and sustainable model for high-volume obstetric centres across Malaysia. The SDA project reflects a proactive commitment to innovation, continuous improvement, and excellence in obstetric perioperative care.

6.12 The Way Forward

Future plans include:

- Expanding SDA eligibility criteria as safety data accumulates
- Conducting joint CME sessions across departments
- Presenting outcomes at OT subcommittee meetings
- Expanding SDA to other eligible surgical pathways
- Advocating for nationwide adoption to support healthcare cost reduction

6.13 Conclusion

The implementation of SDA pathway for elective LSCS at UMMC represents a promising quality improvement initiative in obstetric perioperative care. Through structured protocol development, multidisciplinary collaboration, audit and monitoring, SDA was implemented safely in carefully selected patients and was associated with favourable early clinical, operational, and patient-reported outcomes.

During the pilot period, 128 patients underwent elective LSCS through the SDA pathway, with an estimated cumulative institutional cost saving of RM67,840. These early findings suggest that SDA may improve resource utilisation while maintaining patient safety and a positive patient experience.

As demand for obstetric services continues to increase and healthcare systems face growing resource constraints, SDA has the potential to support patient-centred, value-based maternity care within an ERAC framework. Further expansion and ongoing evaluation will continue to strengthen this initiative, reaffirming our commitment to delivering safe, efficient, and compassionate obstetric anaesthesia care in leading the way to the future of perioperative medicine in Malaysia.

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Optimising Coagulation in Cardiac Surgery

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Abstract

Bleeding remains a major source of morbidity and mortality in cardiac surgery, despite advances in surgical techniques and perioperative care. The complex coagulopathy associated with cardiopulmonary bypass is multifactorial. Among these factors, hypofibrinogenaemia and impaired thrombin generation are the principal contributors to clinically significant bleeding. Contemporary haemostatic management has shifted from empirical transfusion practices towards goal-directed therapy guided by point-of-care viscoelastic testing, including rotational thromboelastometry (ROTEM) and thromboelastography (TEG). These technologies enable rapid identification of specific coagulation abnormalities, facilitating timely, targeted interventions such as fibrinogen replacement, platelet transfusion, prothrombin complex concentrate, and antifibrinolytic therapy while minimising unnecessary allogeneic blood product exposure.

This review summarises the pathophysiology of coagulopathy in cardiac surgery, highlights the limitations of conventional coagulation tests, and examines current evidence supporting viscoelastic-guided bleeding management. It also presents a practical ROTEM-guided treatment algorithm adapted for local clinical practice. Integrating structured haemostatic algorithms within patient blood management programmes has the potential to reduce transfusion requirements, improve haemostasis, and enhance postoperative outcomes in patients undergoing cardiac surgery.

7.1 Introduction

Bleeding remains a significant complication of cardiac surgery despite advances in surgical techniques, cardiopulmonary bypass (CPB), and perioperative management. Excessive bleeding occurs in approximately 10–15% of cardiac surgical procedures and is associated with increased transfusion requirements, re-exploration, prolonged intensive care unit (ICU) stay, and increased morbidity and mortality. Contemporary cardiac surgery, therefore, increasingly emphasises strategies to optimise hemostasis while minimising unnecessary transfusion exposure.[1]

Cardiac surgical bleeding is multifactorial and may result from haemodilution, platelet dysfunction, hypothermia, residual heparin effect, fibrinolysis, and depletion of coagulation factors. Among these mechanisms, hypofibrinogenaemia and impaired thrombin generation are recognised as major contributors to coagulopathic bleeding following CPB.

Over the past decade, hemostatic management has evolved from empirical transfusion practices towards goal-directed therapy guided by point-of-care viscoelastic testing such as rotational thromboelastometry (ROTEM) and thromboelastography (TEG). These modalities provide rapid assessment of clot initiation, clot propagation, clot strength, and fibrinolysis, enabling clinicians to identify specific hemostatic abnormalities and administer targeted therapy in a timely manner.[2]

This review discusses the mechanisms of coagulopathy in cardiac surgery, the role of viscoelastic testing, current treatment strategies, and the application of a local ROTEM-guided bleeding management protocol.

7.2 Causes of Coagulopathy in Cardiac Surgery

7.2.1 Multifactorial Mechanisms

Coagulopathy during cardiac surgery arises from multiple perioperative factors. Exposure of blood to the extracorporeal circuit activates inflammatory and coagulation pathways, leading to platelet dysfunction and consumption of clotting factors. In addition, haemodilution from CPB priming and cardioplegia solutions further reduces platelet and coagulation factor concentrations.

Additional contributors include:

- Hypothermia and metabolic acidosis
- Surgical bleeding and factor consumption
- Anticoagulation with heparin, incomplete reversal or protamine overdose
- Hyperfibrinolysis
- Preoperative antiplatelet or anticoagulant medications

These factors interact and produce a complex haemostatic disturbance that requires targeted management rather than empirical transfusion.

7.2.2 Low Fibrinogen

Fibrinogen plays a central role in haemostasis by forming the fibrin network that stabilises the clot and facilitates platelet aggregation. In cardiac surgery, fibrinogen is frequently the first coagulation factor to decrease to critically low levels during active bleeding.

Hypofibrinogenemia occurs through several mechanisms:

- Haemodilution during CPB
- Consumption during ongoing bleeding
- Activation of fibrinolysis
- Loss through cell salvage and suction

Low fibrinogen levels are strongly associated with increased postoperative bleeding and transfusion requirements. Consequently, early fibrinogen replacement is a key component of modern haemostatic therapy.

Several recent studies support this strategy. A 2024 prospective randomised study comparing fibrinogen concentrate with cryoprecipitate demonstrated that both therapies effectively corrected acquired hypofibrinogenemia after CPB.[3]

Additionally, systematic reviews indicate that fibrinogen concentrate may reduce postoperative blood loss and red blood cell transfusion in patients undergoing cardiac surgery.[4]

These findings reinforce the importance of fibrinogen replacement when clot firmness is reduced.

7.2.3 Reduced Thrombin Generation

Thrombin is the key enzyme responsible for converting fibrinogen into fibrin and activating platelets during clot formation. In cardiac surgery, thrombin generation may be impaired by dilution of coagulation factors, consumption of coagulation factors during bleeding, residual anticoagulant effects, or pre-existing coagulopathy.

Reduced thrombin generation leads to delayed clot initiation and inadequate clot propagation. On viscoelastic testing, this is typically reflected by prolonged clotting time.

Traditionally, fresh frozen plasma (FFP) has been used to replace coagulation factors. However, increasing evidence supports the use of prothrombin complex concentrate (PCC) as an alternative therapy. PCC rapidly restores vitamin K-dependent coagulation factors and can correct factor deficiencies more quickly than plasma transfusion.

Recent clinical studies demonstrate that PCC effectively restores coagulation factor activity and reduces bleeding without increasing the risk of

thromboembolic complications.[5]

7.3 Viscoelastic Testing for Coagulopathy

7.3.1 Limitations of Conventional Coagulation Tests

Conventional laboratory tests, such as prothrombin time, activated partial thromboplastin time, and fibrinogen levels, provide useful information but have important limitations in actively bleeding patients.

These tests:

- Require longer turnaround times
- Assess isolated components of coagulation
- Do not evaluate clot strength
- Correlate poorly with surgical bleeding

Consequently, they are less useful for real-time intraoperative haemostatic management.

7.3.2 Role of Viscoelastic Testing

Viscoelastic haemostatic assays, such as ROTEM and TEG, provide a dynamic assessment of clot formation in whole blood. These tests evaluate clot initiation, clot kinetics, clot strength, and fibrinolysis within minutes.

Viscoelastic testing provides several advantages:

- Rapid point-of-care results
- Identification of specific coagulation defects
- Ability to guide targeted haemostatic therapy
- Reduction in unnecessary transfusion

Meta-analyses and observational studies have shown that viscoelastic-guided transfusion algorithms reduce exposure to allogeneic blood products, postoperative bleeding, and the need for surgical re-exploration.[6]

International guidelines increasingly recommend the use of viscoelastic testing in major surgery. The 2024 cardiac patient blood management guideline emphasises that point-of-care coagulation testing can help predict bleeding risk and guide transfusion strategies in cardiac surgery.[7]

7.3.3 Key ROTEM Parameters

7.3.4 ROTEM Assays

By analysing these parameters, clinicians can rapidly determine whether bleeding is caused by fibrinolysis, platelet dysfunction, fibrinogen deficiency, or impaired thrombin generation.

7.3.5 Treatment Algorithm for Coagulopathy

Goal-directed haemostatic therapy typically follows a structured algorithm based on viscoelastic testing.[8]

7.4 Current Evidence

Recent research continues to support goal-directed haemostatic therapy in cardiac surgery.

Viscoelastic-guided transfusion strategies reduce exposure to blood products compared with conventional laboratory-based management. Randomised trials and meta-analyses demonstrate reductions in red cell, platelet, and plasma transfusion when ROTEM or TEG-based algorithms are used.[7, 9]

Fibrinogen replacement remains central in managing post-CPB coagulopathy. Evidence from randomised trials and systematic reviews supports the use of fibrinogen concentrate or cryoprecipitate to treat acquired hypofibrinogenemia.[7, 10, 11]

PCC is increasingly used to treat coagulation factor deficiency in cardiac surgery because it provides rapid correction of thrombin generation with smaller infusion volumes than plasma.[1, 5]

Finally, integrated patient blood management programmes that combine viscoelastic testing, antifibrinolytic therapy, targeted coagulation factor replacement, and restrictive transfusion strategies have been shown to improve haemostatic outcomes in cardiac surgery.

7.4.1 Local ROTEM-Guided Bleeding Management Protocol

The local ROTEM-guided bleeding management algorithm used in our institution, adapted from the evidence-based framework proposed by Görlinger et al.[8], reflects these contemporary haemostatic principles, as illustrated in Figure 7.1.

7.5 Conclusion

Optimising coagulation in cardiac surgery requires a thorough understanding of the mechanisms underlying perioperative bleeding. Hypofibrinogenemia and impaired thrombin generation remain among the most important and treatable causes of coagulopathy following CPB.

Viscoelastic testing enables rapid identification of haemostatic abnormalities and facilitates goal-directed therapy. Contemporary evidence supports the use of fibrinogen replacement, PCC for coagulation factor deficiency, and antifibrinolytic therapy as part of structured bleeding management algorithms.

The integration of ROTEM-guided haemostatic strategies within patient blood management programmes has the potential to reduce transfusion requirements, improve haemostasis, and enhance overall clinical outcomes in cardiac surgery.

Table 7.1: Key ROTEM Parameters

Parameter	Clinical Significance
Clotting Time (CT)	Reflects the initiation phase of coagulation and thrombin generation.
Amplitude at 5 minutes (A5)	Provides early information on clot firmness (due to fibrinogen and platelets) and possible hyperfibrinolysis.
Maximum Lysis (ML)	Indicates the presence of hyperfibrinolysis.

Table 7.2: ROTEM Assays

Assay	Description
INTEM	Intrinsic pathway, sensitive to heparin.
HEPTEM	INTEM with added heparinase, neutralises the heparin effect.
EXTEM	Extrinsic pathway, insensitive to heparin; amplitude reflects platelet and fibrinogen contributions.
FIBTEM	EXTEM with added antiplatelet agent; amplitude is specific to fibrin polymerisation.
APTEM	EXTEM with added antifibrinolytics; normalises the EXTEM result in hyperfibrinolysis.

Table 7.3: Treatment Algorithm for Coagulopathy

Step	Clinical Action
1. Confirm active bleeding	Before initiating haemostatic therapy, surgical causes of bleeding must be excluded. Targeted treatment is most effective when coagulopathic bleeding is identified early.
2. Hyperfibrinolysis	If viscoelastic testing indicates hyperfibrinolysis, antifibrinolytic therapy should be administered. Tranexamic acid remains the first-line agent and is routinely used in cardiac surgery to reduce bleeding.
3. Residual heparin effect	Residual heparin after CPB may impair clot initiation. Comparison of INTEM and HEPTEM assays allows identification of residual heparinisation, which should be treated with additional protamine.
4. Inadequate clot strength	If clot strength is inadequate, EXTEM and FIBTEM parameters can help identify the underlying cause. • EXTEM <30 mm and FIBTEM <9 mm suggests hypofibrinogenaemia. • EXTEM <30 mm with normal FIBTEM suggests platelet deficiency. Hypofibrinogenaemia should be treated with fibrinogen concentrate or cryoprecipitate. If EXTEM remains low after fibrinogen correction, platelet transfusion may be required.
5. Impaired thrombin generation	Prolonged clotting time with adequate clot strength indicates impaired thrombin generation. Treatment may include prothrombin complex concentrate (PCC) or fresh frozen plasma.

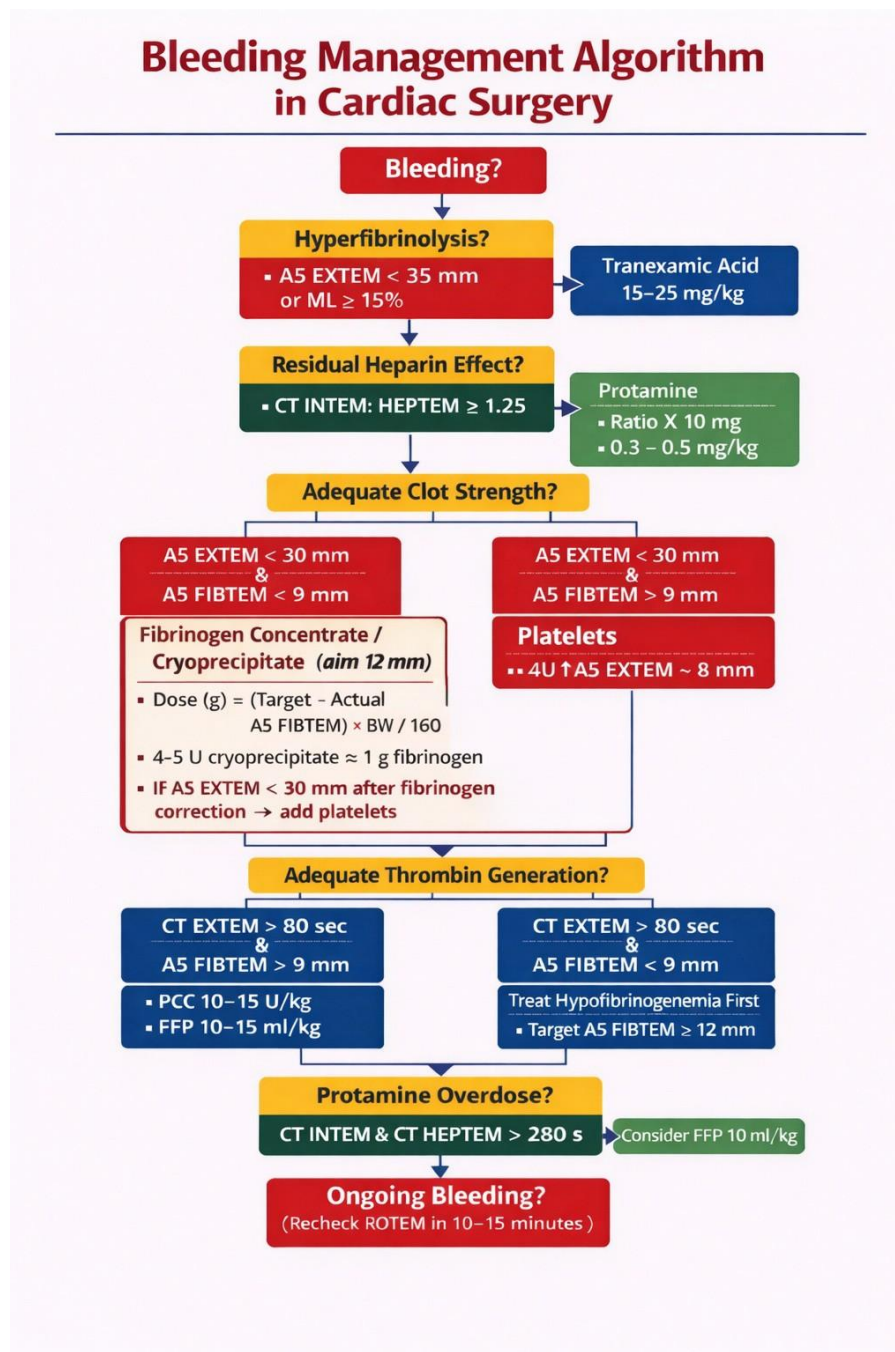


Figure 7.1: Bleeding Management Algorithm in Cardiac Surgery: local ROTEM-guided protocol, adapted from Görlinger et al.[8]

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Part II

Supportive Teamwork

Supportive Teamwork: The Anaesthesiology Avengers Team

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Abstract

Malaysia's public healthcare system is facing unprecedented pressures from increasing patient demands, workforce shortages, funding constraints, and an increasingly complex healthcare landscape. In this challenging environment, supportive and effective teamwork within anaesthesiology has become essential to maintaining patient safety, staff well-being, and high-quality perioperative care.

Using the analogy of “The Anaesthesia Avengers”, this article explores the attributes required to build a supportive teamwork within anaesthesia departments. Drawing parallels with familiar superhero characters, it highlights essential team roles including leadership, ethical advocacy, situational awareness, crisis management, and emotional regulation. The emphasis on effective teamwork extends beyond clinical expertise and encompasses psychological safety, mutual respect, open communication, and shared accountability.

8.1 Introduction

Teamwork in anaesthesiology is often invisible to the public eye. Yet, it is the very backbone of safe perioperative care, and we anaesthesiologists know the invaluable role we play in patient care. Much like the team dynamics portrayed in the Avengers, where individuals with different strengths unite to protect the world, the anaesthesia team comprises professionals with varied expertise working cohesively to safeguard patients.

However, unlike cinematic heroism, teamwork in the healthcare industry is grounded in reality. There is fatigue, emotional strain, personal sacrifice, and at times, unspoken struggles. No team is without conflict. Not every situation is within our control. What remains within our control is our mindset, our professionalism, and our response to adversity. Supportive teamwork in anaesthesiology is therefore not merely just about technical competence, it is about emotional intelligence, mutual respect, and shared purpose.

8.2 The Foundation of Supportive Teamwork

Before examining roles within the team, we must acknowledge the reality that every healthcare worker carries personal burdens e.g. financial pressures, family responsibilities, domestic stressors, and emotional fatigue. These external factors inevitably shape behaviour and interactions.

Yet, within the hospital environment, professionalism requires a deliberate shift in mindset. A supportive team is built when individuals consciously choose to:

- Strive for continuous improvement
- Communicate openly and respectfully
- Maintain awareness of personal distress while consciously preventing it from affecting patient-centred responsibilities
- Extend empathy to colleagues

Supportive teamwork does not mean the absence of hardship; rather, it is the ability to function effectively despite it. After all, to err is human. It is our shared responsibility as professionals to seek balance in our lives, learn from our errors, and extend understanding and support to one another along the way.

The operating theatre and acute care environment are inherently complex and often stressful. Stress directly impacts cognition and can lead to tunnel vision. Strong teamwork, however cliché it may sound, is a crucial step towards ensuring patient safety and fostering healthy team dynamics.[1]

Let us now turn to the case of the “Anaesthesia Avengers” and explore how each archetype within the team contributes to building a culture of supportive anaesthesia practice.



Figure 8.1: The Anaesthesia Avenger team.

8.3 Iron Man — The Leader

In Iron Man, Tony Stark is described as a self-proclaimed genius who builds a powerful armour to fight threats beyond the ordinary capability of an average human. In the Avengers, he is innovative, decisive, and often takes initiative.

In anaesthesiology, the Iron Man represents the Team Leader i.e. the consultant or senior anaesthesiologist overseeing perioperative management, establishing clear behavioural standards and creating a highly engaged workforce.

Leadership in anaesthesia does not require a genius, but it demands:

- Clinical competence
- Decisiveness under pressure
- Situational awareness
- Accountability

Within many Asian healthcare settings, cultural norms may encourage hierarchy and deference. Junior team members may hesitate to speak up. A strong leader must therefore cultivate psychological safety by actively inviting input, discouraging favouritism, and modelling humility.

It is true that maintaining harmony within a team is challenging. Even within families, it is difficult to keep everyone content. However, when the leader's intention is patient safety and collective growth, trust develops naturally. A true anaesthesia leader does not dominate but rather empowers the team.

8.4 Captain America — The Moral Compass

In Captain America: The First Avenger, Steve Rogers embodies integrity, discipline, and unwavering commitment to doing what is right even when it is difficult.

In the Anaesthesia Avengers Team, Captain America symbolises the ethical anchor of the department.

This role should be held by all team members, be it junior or senior:

- Upholds patient advocacy
- Speaks up when safety is compromised
- Maintains professionalism in conflict

Supportive teamwork thrives when there is moral courage. When a junior officer questions a drug dose, when a nurse clarifies an unclear instruction, or when a trainee highlights a potential airway difficulty, these actions reflect Captain America's spirit.

A culture that supports respectful expression of thoughts prevents harm. Silence, in contrast, can be dangerous. The Asian mindset that deems speaking out or questioning a decision as an act of disrespect towards authority remains a challenge in deep-seated cultural and professional hierarchies and we should work towards breaking those boundaries to improve patient care.

8.5 Black Widow — The Master of Situational Awareness

In Black Widow, Natasha Romanoff is observant, strategic, and highly perceptive. She notices subtle cues others may overlook.

Within anaesthesia, Black Widow represents:

- The experienced anaesthesia nurse
- The vigilant assistant
- The perceptive trainee

The New Zealand Health and Disability Commission report in 2024 described a patient who died from a pulmonary embolism 16 hours after being admitted to hospital.[2] Several staff had documented that her condition was getting worse, but no one stopped to reassess the overall plan. No one took a step back to ask, "Is this still the right diagnosis?" or "Why isn't she improving?"

Each clinician saw pieces of the problem, but the team as a whole did not connect the dots. This is an example of loss of team situation awareness. People can become focused on the original diagnosis and unintentionally ignore new signs that suggest something different. This is known as cognitive bias; we tend to look for information that supports our first decision and overlook conflicting clues.

Maintaining situational awareness requires someone to take that fresh look; to pause, reassess, question assumptions, and voice concerns. It requires a team culture where vigilance is valued, curiosity is encouraged, and hierarchy does not silence observation.

Supportive teamwork means recognising and respecting the "Black Widow" in the room i.e. the experienced nurse, vigilant assistant, or perceptive trainee who notices the subtle change before it becomes a catastrophe.

8.6 Thor — The Crisis Responder

Thor embodies strength and taking decisive actions in moments of chaos. The "Thor" of the team may be the airway expert, the resuscitation lead, or the most composed clinician during a code.

Supportive teamwork ensures that crisis response is structured not ego-driven. Simulation training, clear role allocation, and closed-loop communication transform chaos into coordinated action.

8.7 Hulk — Emotional Regulation

The Hulk represents immense power but also the danger of uncontrolled emotion. In high-stress environments such as the operating theatre or intensive care unit, emotional dysregulation can damage team cohesion.

In anaesthesia practice, the "Hulk lesson" reminds us that:

- Stress is inevitable
- Anger is understandable
- Public humiliation is harmful

Supportive teamwork requires emotional maturity. Feedback should be constructive, not destructive. Private correction is preferable to public criticism. Departments that foster kindness experience lower burnout and better retention.

Equally, when feedback is received, it deserves thoughtful reflection. One should evaluate it with openness and professionalism. At times, feedback may feel like a bitter pill to swallow. In such moments, it is wise to pause rather than react defensively while allowing space to process, reconsider the intention behind the message, and reflect on whether there is any truth to learn from the incident. That pause itself reflects maturity. When needed, seeking perspective from a trusted mentor or colleague can help transform discomfort into growth.

A workplace culture that tolerates gossip, subtle put-downs, negative story-telling, or labelling colleagues can quietly erode trust and psychological safety. Such behaviours may seem trivial in isolation, but over time they fracture cohesion, discourage open communication, and create unnecessary tension within the department. If we aspire to be a harmonious and high-functioning anaesthesia team, these patterns

must be consciously discouraged and replaced with professionalism, respect, and honest dialogue.

8.8 From Analogy to Practice

To translate analogy into practice, departments should prioritise:

1. **Psychological Safety** — Encourage open communication without fear of ridicule.
2. **Structured Briefings and Debriefings** — Pre-list briefings and post-case reflections enhance clarity and learning.
3. **Simulation Training** — Strengthens crisis teamwork and role clarity.
4. **Well-being Initiatives** — Addresses burnout, moral injury, and compassion fatigue.

Supportive teamwork is not accidental. It is cultivated intentionally through policy, leadership, behaviour, and shared accountability.

8.9 Conclusion

Anaesthesiology is a specialty defined by vigilance, precision, and quiet heroism. Like the Avengers, no single member can function optimally alone. Each role, be it the leader, advocate, observer, crisis responder or emotional stabiliser remains essential.

Unlike cinematic narratives, there is no dramatic applause at the end of a safe anaesthetic. The reward is subtler: a stable patient, a successful surgery, and a team that remains united despite challenges. Supportive teamwork in anaesthesiology is not about perfection. It is about commitment to patients, to colleagues, and to continuous growth.

If we strive daily to improve our mindset, refine our communication, and uplift one another, then perhaps our operating theatres will not only be safe but truly a supportive environment worthy of the name: The Anaesthesia Avengers Team.

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Teamwork in Futuristic Anaesthesia: The Human Foundation for Future-Ready Practice

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KEY POINTS

- Supportive teamwork is fundamental in the provision of safe anaesthesia; technical excellence alone is insufficient.
- Psychological safety empowers clinicians to speak up, learn from errors and improve patient outcomes.
- Caring for the healthcare team, including support for second victims, remains essential for workforce resilience.
- Malaysian anaesthesia practice demonstrated the value of multidisciplinary teamwork across diverse healthcare settings.
- AI provides a complementary role as the future belongs to a high-performing human–AI team.

9.1 Introduction

Anaesthesia practice is becoming increasingly complex, driven by ageing populations, rising comorbidities, expanding perioperative roles, and rapid technological advancement. In this evolving landscape, being “future-ready” extends beyond technical expertise and innovation. It requires robust human systems that support safe, adaptive, and sustainable care. Supportive teamwork is central to this transformation.

Anaesthesia is inherently team-based. Safe care depends on effective communication, shared decision-making, leadership, and mutual trust among anaesthesiologists, surgeons, nurses, and allied health professionals. Increasingly, this teamwork extends to the integration of artificial (AI) and digital technologies—ranging from predictive analytics and decision-support systems to automated monitoring platforms—which can enhance situational awareness, reduce cognitive load, and support clinical decision-making.[1, 2] However, these tools are only as effective as the teams that use them.

Evidence from high-reliability industries and healthcare consistently shows that failures in teamwork and communication contribute more to adverse events than deficiencies in technical skill alone.[3, 4] As healthcare systems face workforce shortages, increasing service pressures, and rapid digital transformation, supportive teamwork that is human and technology-enabled is no longer optional; it is a core clinical competency essential for patient safety and workforce resilience.

9.2 Current Practice

9.2.1 Teamwork and Patient Safety

Teamwork is recognised as a critical patient safety intervention in anaesthesia and perioperative care. Studies have demonstrated that structured communication, shared mental models, and coordinated team behaviour reduce perioperative errors and improve outcomes, particularly during crises and complex procedures.[5, 4] In high-stakes clinical scenarios such as a “can’t intubate, can’t oxygenate” airway crisis or uncontrolled haemorrhage, the difference between recovery and catastrophe often lies not in individual technical skill, but in how effectively the team communicates, anticipates, and executes under pressure. The operating theatre, ICU, and emergency settings are environments where cognitive load is high and margins for error are small. In these moments, teamwork is not merely supportive but it is lifesaving.

9.2.2 Psychological Safety and Speaking Up

Psychological safety underpins effective teamwork. It enables team members to raise concerns, challenge

decisions, and report near-misses without fear of blame. In anaesthesia, where early recognition of deterioration or system failure is vital, the ability of any team member to speak up can be life-saving. Evidence shows that teams with high psychological safety demonstrate better error detection, learning behaviour, and adaptive performance.[3, 6] Leadership behaviours that encourage openness, respectful communication, and non-punitive responses to error are key to fostering this environment.

9.2.3 Leadership in Anaesthesia Teams

Leadership in anaesthesia has evolved from traditional hierarchical models towards situational and shared leadership approaches. Effective leaders adapt their style to the clinical context, providing clear direction during crises while promoting collaboration and learning during routine care. Leadership behaviours such as role clarity, anticipation of problems, calm decision-making, and emotional regulation have been shown to improve team performance during critical events.[7, 5] Importantly, leadership in anaesthesia is not limited to formal roles but is exercised dynamically at the bedside.

9.2.4 Team-Based Training and Simulation

Teamwork skills require deliberate training. Simulation-based education, particularly interprofessional simulation, is an established method for developing both technical and non-technical skills in anaesthesia.[5, 8] Crisis Resource Management (CRM) training emphasises communication, situational awareness, leadership, and teamwork, and has been associated with improved team performance and patient safety. Simulation also provides a psychologically safe environment for learning from error without patient harm.

9.2.5 Workforce Well-Being and Team Performance

Workforce well-being is closely linked to teamwork and patient safety. Burnout and fatigue impair communication, decision-making, and empathy, increasing the risk of adverse events. Supportive teams mitigate these risks by sharing workload, providing peer support, and fostering a sense of belonging. Evidence consistently shows that positive team climates are associated with improved staff satisfaction, retention, and resilience, reinforcing the role of teamwork as both a safety and sustainability strategy.[9, 10]

Beyond system performance, adverse events also carry a profound emotional and psychological impact on healthcare providers known as the *second victim* phenomenon. Anaesthesiologists and team members involved in complications such as airway crises, perioperative cardiac arrest, or unexpected mortality

may experience guilt, self-doubt, anxiety, and even long-term burnout. Without adequate support, this can impair future performance and contribute to attrition.

Supportive teams play a critical protective role in this context. Informal peer support, a simple “are you OK?” after a difficult case, and structured post-event debriefing—whether after a failed airway, major haemorrhage, or ICU deterioration—can provide opportunities for emotional processing, shared reflection, and collective learning. Even if these sessions are kept brief, well-conducted debriefs can normalise reactions, reduce stigma, and transform distress into constructive improvement. Over time, this fosters a healthier learning culture and strengthens team cohesion, ensuring that individuals are supported rather than isolated after adverse events.[9]

9.2.6 Local Perspective and Experience

In the context of our country, anaesthesia teams operate across diverse settings with varying levels of resources and manpower. Supportive teamwork is particularly critical in district hospitals and during on-call periods, where small teams often manage high workloads with limited backup. In such environments, effective MO–specialist relationships characterised by approachability, psychological safety, and timely supervision are essential not only for patient safety but also for clinician confidence and development.

Real-world practice often reflects this. Having previously served as the sole anaesthetist in a district hospital, I witnessed firsthand how a single anaesthetist and a small team may need to manage back-to-back emergency cases such as a ruptured ectopic pregnancy followed by a trauma laparotomy requiring rapid coordination, clear communication, and mutual trust. Similarly, in tertiary centres, high-acuity cases such as obstetric haemorrhage, major trauma, or complex surgical emergencies demand seamless collaboration between anaesthesia, surgical, emergency, and intensive care teams. In these situations, shared mental models, situational awareness, and anticipatory teamwork are not merely desirable attributes; they are what keep the system functioning safely and effectively under pressure.

Multidisciplinary collaboration is therefore central to modern anaesthesia practice in Malaysia, particularly in trauma care, obstetrics, critical care, and perioperative medicine. Clear communication during handovers, joint planning for high-risk cases, and mutual respect across disciplines are key enablers of safe care. Increasingly, there is also recognition of the need for structured post-event support following critical incidents. While formal second victim support programmes are still evolving locally, many departments have begun integrating debriefing practices after major events such as maternal collapse or unexpected ICU mortality as part of routine care.

These efforts, even when simple and resource-limited, represent an important shift: from a culture of silent endurance to one of shared responsibility and support. In doing so, they not only enhance patient safety but also cultivate stronger, more cohesive teams capable of sustaining high-quality care in demanding environments.

9.3 Challenges and Gaps

Persistent hierarchical culture may inhibit speaking up, particularly among junior staff. Service pressures and manpower constraints limit opportunities for team training, simulation, and structured debriefing. Access to leadership development and non-technical skills training remains variable across institutions. Addressing these challenges requires organisational commitment and system-level solutions rather than reliance on individual resilience alone.

9.4 Future Directions and Conclusion

Future-ready anaesthesia demands intentional investment in supportive teamwork. Psychological safety must be embedded in daily practice through leadership behaviour, open communication, and non-punitive learning systems. Leadership and teamwork training should be integral to professional development, while institutions must recognise workforce well-being as central to patient safety and sustainability.

As AI and digital systems become integrated into perioperative care through predictive analytics, automated delivery systems, and decision-support tools, teams must adapt to human–AI collaboration. The safe use of these technologies depends on how clinicians engage with them. Automation bias and the tendency to over-rely on algorithmic outputs poses a real risk, potentially leading to delayed recognition of clinical deterioration or unquestioned acceptance of recommendations.[1, 11, 2]

Effective human–AI teamwork requires maintaining clinical vigilance, understanding system limitations, and fostering a culture where both human and machine decisions can be questioned. Technology should enhance, not fragment communication and shared mental models within the team.

Ultimately, while technology will continue to evolve, it is supportive teamwork that will determine the safety, resilience, and sustainability of anaesthesia services.

“Machines can assist—but when it matters most, the call is still ours.”

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Effective Team Leadership in Anaesthesia and Perioperative Care

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Abstract

The evolution of anaesthesiology from a technical craft to a system-wide discipline necessitates effective leadership across the entire perioperative journey. This chapter explores the theoretical foundations of anaesthesia leadership, emphasizing transformational and authentic leadership models that foster psychological safety, reduce burnout, and build team resilience. It highlights the cognitive dimensions of team coordination, specifically Team Situation Awareness (TSA) and shared mental models, as critical components for navigating high-stakes clinical environments. Furthermore, effective communication frameworks such as Situation, Background, Assessment, Recommendation (SBAR) and Stop, Notify, Assessment, Plan, Priorities, Invite Input (SNAPPI) are discussed for their vital role in adaptive coordination and error prevention. Beyond direct clinical care, anaesthesiologists are increasingly required to act as change agents within healthcare administration. By utilizing organizational development frameworks—such as Weisbord’s 6-Box Model, the Bridges Transition Model, and Kotter’s 8-Step Model—leaders can successfully implement and sustain systemic changes. These competencies are particularly crucial in high-acuity scenarios such as trauma management, where structured protocols and interdisciplinary collaboration dictate patient survival. Ultimately, strong clinical governance and proactive team management ensure that anaesthesiology remains central to delivering safe, value-based patient care.

10.1 Introduction

The historical trajectory of anaesthesiology represents one of the most remarkable transformations in the history of medicine. What began as a technical craft, primarily focused on the physical act of stopping pain, has blossomed into a complex, system-wide discipline that demands leadership at every level of care. In the mid-19th century, leadership was a solitary pursuit, defined by the courage of individuals who operated in an era where surgical outcomes were often unpredictable. Pioneers like William Morton and John Snow paved the way through personal grit and a commitment to scientific observation. They established the safety pillars we still rely on today, yet their world was limited to the immediate administration of an agent and the recording of a reaction.[1, 2]

In those early days, leadership was synonymous with technical mastery, a singular focus on the clinician's ability to manipulate pharmacology. Today, however, the anaesthesiologist has moved from the head of the operating table to a much larger stage. We are now orchestrators of value, leading multidisciplinary teams through the entire perioperative journey, from the first surgical consultation to the moment a patient returns home. This evolution requires a style of leadership that balances clinical precision with a deep understanding of human behaviour and hospital systems. Historically, Virginia Apgar showed us that this transition was possible; her legacy is not just a score for newborns, but a model for how one leader can bridge the gaps between obstetrics, paediatrics, and anaesthesia to create a safer environment for everyone.[1]

10.2 Theoretical Foundations of Anaesthesia Leadership

In the high-pressure worlds of the operating room and the intensive care unit (ICU), the way we lead directly impacts whether our teams remain resilient or crumble under stress.[2, 3] Leadership here is more than just a set of instructions; it is an emotional and intellectual anchor. Models like transformational leadership allow us to move beyond simple orders by promoting a shared vision and treating every team member as a person. When anaesthesiologists lead this way, they do not just complete a list of tasks; they inspire their teams to aim for excellence.

Evidence shows that this approach leads to higher job satisfaction and protects clinicians from the heavy burden of burnout, which is often the price of more rigid, transactional styles.[3, 4, 5] Alongside this, authentic leadership brings a much-needed sense of transparency and self-awareness to the field. At its heart is the creation of psychological safety, the quiet but powerful belief that anyone in the room can speak up if they see a problem without fear of being shamed or punished.[3, 4, 6] When a leader is honest about their own challenges or uncertainties, they give the rest of

the team permission to be honest too. This culture of transparency is often the only thing standing between a minor complication and a catastrophic error.

While a strict, rule-following approach might work for routine tasks, it often fails when a crisis hits and the team needs to think on its feet.[2] This has led to the rise of relational leadership models, which focus on building bridges between different hospital departments. The Lead Infinitely framework suggests that anaesthesiologists are uniquely positioned to influence the entire healthcare ecosystem by using their skills in consensus-building.[1, 7] This view of leadership is an infinite game, where the goal is not to win a quick argument with a colleague, but to build a workspace that sustains everyone over the long term.

By finding early adopters of new ideas, anaesthesia leaders can champion changes that make the whole hospital safer and more efficient. This is perhaps most visible in the success of Enhanced Recovery After Surgery (ERAS) programs, where the entire team must pull in the same direction to achieve the best results for the patient.[8] The implementation of such programs is not merely a change in clinical protocol but a transformation of the surgical culture itself, requiring the anaesthesiologist to serve as a diplomat and an advocate for evidence-based practice across various specialties.

10.3 Cognitive Dimensions and Team Coordination

Leadership in our field also has a profound cognitive side, particularly in how we maintain Team Situation Awareness (TSA). This is the process of seeing what is happening, understanding its meaning, and predicting what might happen next.[1, 9] When we are under extreme stress, we are all prone to tunnel vision, focusing so hard on a single task that we lose sight of the bigger picture. A skilled leader fights this by stepping back and using the collective eyes and ears of the entire team. By inviting input and keeping everyone informed, the leader maintains a Shared Mental Model, ensuring that everyone in the room has the same understanding of the plan and their role within it.[9] Research reminds us that these mental models are fragile; while teams often agree on when to do something, they only agree on who should do it about 39% of the time.[2, 9] This is why huddles and recaps are so vital; they keep the team's trajectory aligned when the stakes are at their highest. A leader who fails to check in with their team is essentially flying blind, relying on luck rather than a shared understanding of the environment.

In the best-performing teams, leadership is rarely a one-man show; instead, it is shared.[2, 6, 10] This means that leadership moves around the room depending on who has the expertise needed at that moment. An anaesthesia nurse might take the lead on a specific piece of equipment, while the senior clinician focuses

Table 10.1: Comparison of Leadership Styles in Anaesthesia

Leadership Style	Defining Behaviours	Impact on Team Dynamics and Resilience
Transformational	Inspirational motivation, intellectual stimulation, shared vision	Higher resilience, increased job satisfaction, and role effectiveness[3]
Authentic	Transparency, ethical conduct, balanced processing, self-awareness	Enhanced trust, positive role modelling, and supportive environment[1]
Transactional	Strict protocol adherence, rewards/punishments, hierarchical focus	Increased risk of burnout, reduced autonomy, and limited adaptability[1]
Passive-Avoidant	Avoidance of decisions, delayed responses, non-engagement	Undermined team confidence and ineffective crisis management[1]

Table 10.2: Levels of Team Situation Awareness (TSA) in Perioperative Care

TSA Level	Cognitive Action	Perioperative Application
Perception	Monitoring environmental cues	Observing changes in vitals, surgical progress, and monitor alarms[1]
Comprehension	Synthesizing information	Interpreting a drop in end-tidal carbon dioxide (CO ₂) as potential arrest or embolus[1]
Projection	Predicting future states	Anticipating airway challenges or the need for emergency blood[1]

on coordinating the overall safety of the patient. This approach relies on transactive memory, the simple but effective knowledge of who knows what within the group, which helps lower the mental load for everyone.[2, 5]

During a crisis, a leader might intentionally step back from a physical task to maintain a macro-level view of the situation, ensuring that nothing is missed while the rest of the team works. This highlights the importance of the relationship between the surgeon and the anaesthesiologist. This partnership must be a united front, especially during difficult cases where surgical goals and medical safety might seem at odds. Collaborative decision-making is the lifeblood of successful programs, allowing clinicians to align their strategies from the very first preoperative meeting until the patient is fully recovered.[2, 8, 10]

10.4 Communication and Adaptive Coordination

To prevent the communication failures that lie at the heart of 70% of medical errors, we rely on standardised tools that keep everyone on the same page.[2] Central to this is the Situation, Background, Assessment, Recommendation (SBAR) framework, which serves as a structured method for information exchange during critical handovers. In the perioperative setting, the Situation focuses on why the patient is currently in

the operating theatre, while the Background provides the medical context, such as significant comorbidities or preoperative allergies. The Assessment allows the clinician to synthesise current vital signs and surgical progress into a clear clinical picture, followed by a specific Recommendation for the next steps in care. By standardising this dialogue, leaders ensure that vital data is not lost in translation during high-stakes transfers.

Equally important for intra-procedural coordination is the Stop, Notify, Assessment, Plan, Priorities, Invite Input (SNAPPI) framework, which is designed to facilitate brief but effective surgical pauses or “re-caps” when a clinical situation evolves. A leader initiates the process by calling for a Stop, ensuring the team’s attention is secured. This is followed by a Notify phase to explain the new event or concern. The Assessment and Plan stages allow for a quick collective review of the immediate strategy, while the Priorities phase re-aligns the team on the most critical task at hand. Critically, the framework concludes with Invite Input, which actively flattens the hierarchy and encourages every team member to share relevant observations. This proactive seeking of feedback is a hallmark of inclusive leadership.

In emergencies, closed-loop communication becomes our most important tool, ensuring that every order is heard, understood, and carried out correctly. Our coordination must be adaptive, shifting between the quiet, implicit understanding of a routine case and the

Table 10.3: Adaptive Coordination Patterns in Anaesthesia

Work Phase	Task Load	Coordination Style	Leadership Behaviour
Routine	Low	Implicit	Monitoring, non-interference, following standards[10]
Non-Routine	High	Explicit	Directive leadership, clear commands, role reassignment[1]
Crisis Initiation	Critical	Directive	Establishing medical priorities, calling for help[1]
Crisis Maintenance	Critical	Explicit	Re-establishing shared mental model, closed-loop comms[10]

loud, directive leadership needed during a crisis.[1, 5, 10] This adaptive behaviour is a skill that must be honed through simulation and repeated practice, as the cognitive shift required to move from a collaborator to a commander is significant.

Effective perioperative management requires the anaesthesiologist to move beyond clinical skill into the realm of healthcare administration, where the management of resources, scheduling, and staff morale becomes just as important as the management of the patient's physiology. This administrative role is often overlooked but remains essential for the sustainability of surgical services.

10.5 Organisational Change and Healthcare Administration

Today, anaesthesia leaders must also be change agents, navigating the complex social and institutional structures of a hospital to implement new clinical pathways or technologies. This is where the application of organizational development models becomes essential for effective healthcare administration. The Weisbord 6-Box Model is an invaluable tool for this, helping leaders diagnose the health of their department by looking at six critical areas as outlined in Figure 10.1. This diagnostic process enables leadership to identify systemic friction, such as a lack of ideological alignment regarding departmental objectives, suboptimal inter-professional synergy, or mechanisms that fail to provide tangible utility. In an administrative context, the anaesthesiologist must ensure the departmental structure supports the clinical mission while remaining financially viable.

The process of change in the perioperative setting is not merely a matter of updating systems; it is a deeply human endeavour. The Bridges Transition Model distinguishes between situational change and psychological transition, which typically takes much longer.[1] As detailed in Figure 10.2, people must navigate through internal psychological phases to achieve a successful outcome. Effective anaesthesia leaders provide the empathy and clarity required to

navigate these phases safely, recognising that friction in the Neutral Zone is often a sign of healthy adjustment rather than outright resistance. By managing this transition, leaders can prevent a drop in morale and ensure patient safety is not compromised during institutional flux.

For large-scale projects, such as the national rollout of standardised trauma protocols, Kotter's 8-step model (Figure 10.3) provides a strategic roadmap for anchoring new habits into the departmental culture.[1] This begins with establishing urgency, followed by forming a powerful coalition, and communicating a vision relentlessly. Leaders must empower action by removing bottlenecks and celebrating short-term wins to sustain momentum. Ultimately, the change must be anchored in the culture. In healthcare administration, this systematic approach ensures that innovations in safety are sustained.[11]

10.6 The Malaysian Professional Context

In the Malaysian context, this journey is supported by a strong regulatory framework that has evolved to meet the needs of a modernising healthcare system. The National Postgraduate Curriculum for Anaesthesiology and Critical Care (2024) and the Medical (Amendment) Act 2024 have made leadership a core part of what it means to be a specialist.[12] Anaesthesia postgraduate trainees are now expected to show leadership in multidisciplinary teams and solve problems creatively under pressure. In their final years, they take on real leadership roles, mentoring junior colleagues and managing operating room workflows.

Healthcare administration in Malaysia requires anaesthesiologists to engage deeply with hospital directors and the Ministry of Health to ensure clinical standards are maintained across sectors. Yet, a major challenge remains the protection of clinical autonomy in an increasingly administrative environment. In an era driven by financial metrics and Third-Party Administrators (TPAs), we must be fierce advocates for our patients. We must ensure medical decisions

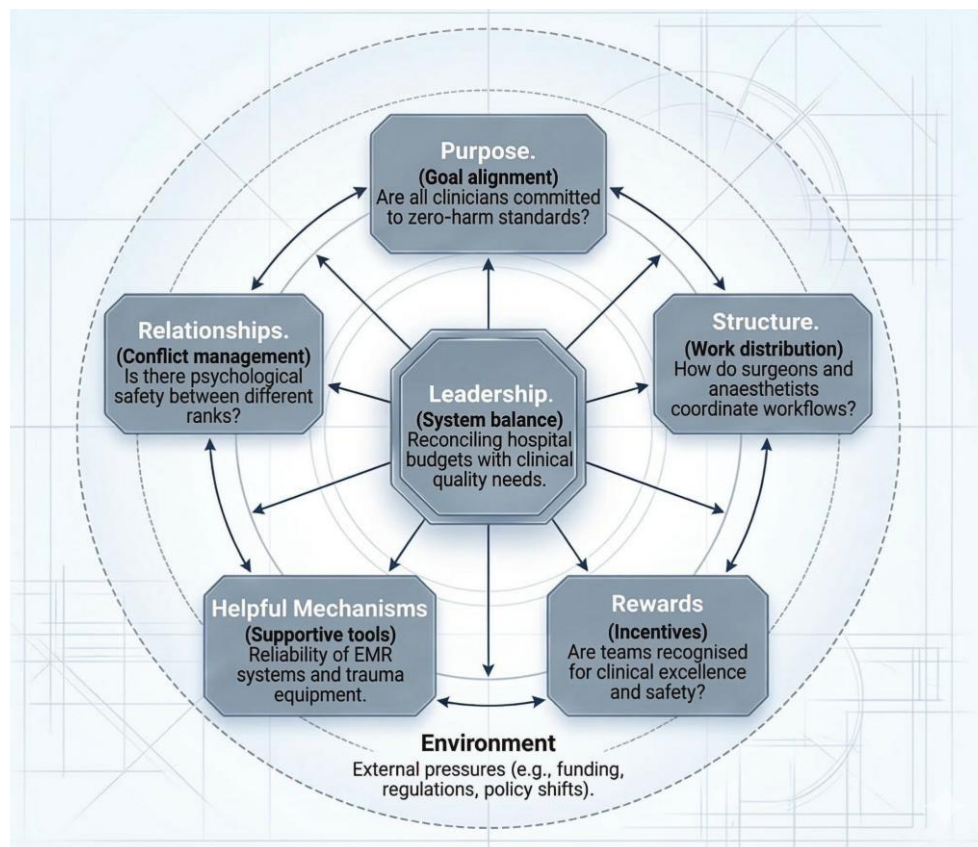


Figure 10.1: Weisbord's 6-Box Model for Organisational Diagnosis.

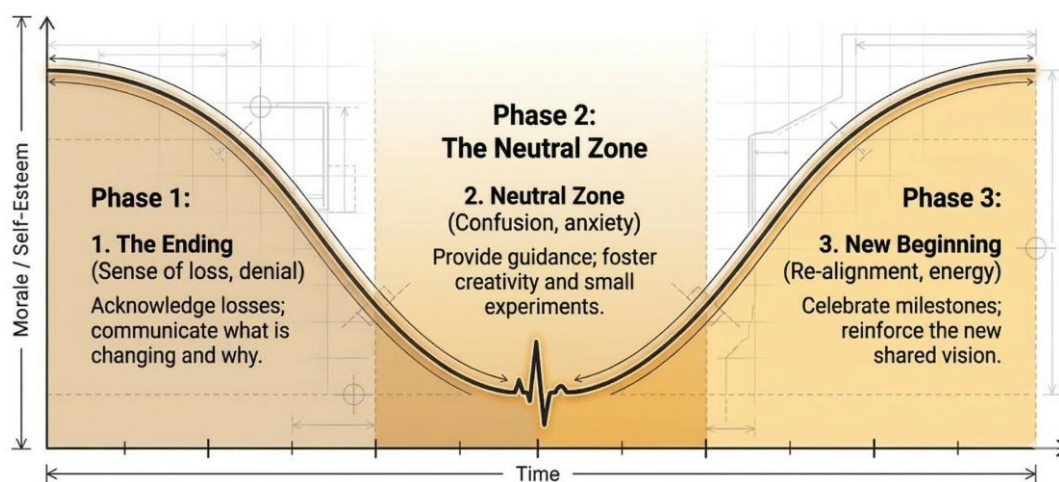


Figure 10.2: Bridges Transition Model: Navigating Psychological Change.

are based on the patient's best interest rather than financial directives.[9, 13] This requires significant moral courage and the ability to stand firm in clinical judgment.[14]

Trauma care is another critical arena for leadership in Malaysia, where trauma remains a leading cause of mortality.[15] Managing a major trauma case requires synchronized, multidisciplinary discussions where time is the greatest enemy. In high-pressure moments, clear communication and standard protocols are the difference between life and death.[2, 16] The Malaysian

Society of Anaesthesiologists has been at the forefront of standardizing these responses nationwide. From an administrative perspective, this requires coordination of blood banks, emergency theatres, and ICU bed management.

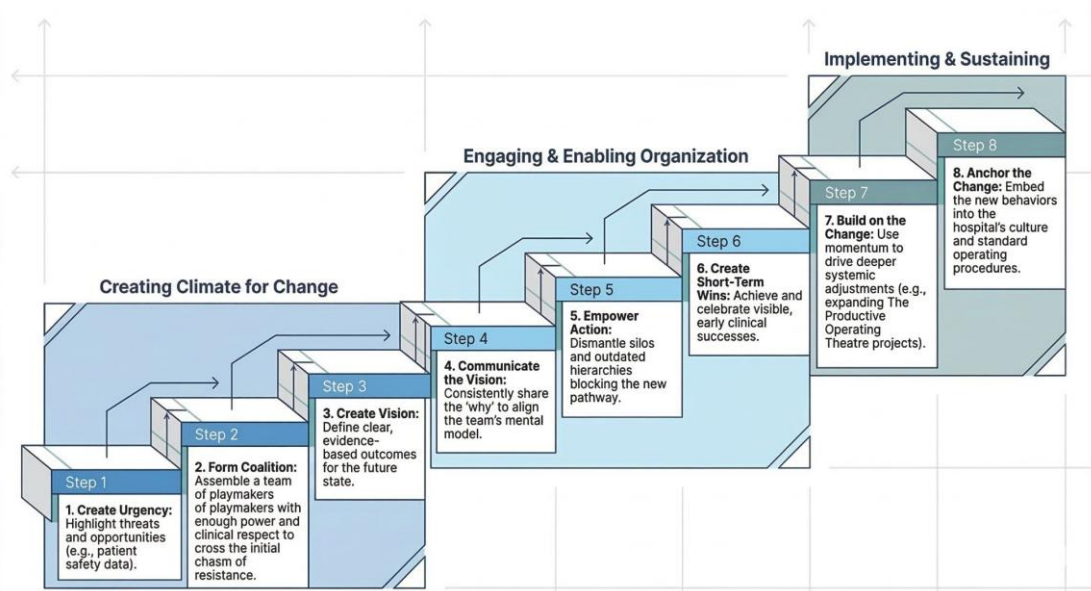


Figure 10.3: Kotter's 8-Step Model for Leading Change.

10.7 Clinical Governance and Strategic Planning

Effective perioperative dynamics are further enhanced by clinical governance structures that prioritise quality improvement and patient safety. Anaesthesia leaders are now increasingly involved in planning perioperative surgical homes, a model focusing on continuity of care and reduced complications.[17] This requires a deep understanding of healthcare operations, patient flow, and preoperative clinic optimization. By leading these administrative initiatives, anaesthesiologists ensure value-based care that is safe and efficient.

The administrative burden continues to grow as regulatory bodies demand more detailed documentation and outcome reporting. Leaders must develop the skills to analyse big data, manage supply chains, and negotiate contracts with hospital vendors. While these administrative tasks may appear disconnected from direct patient care, their relevance in a perioperative and trauma setting is profound. Effective supply chain management and data-driven resource allocation ensure that life-saving equipment—such as massive transfusion protocol kits, specialised difficult airway adjuncts, and targeted trauma medications—are immediately available during a mass casualty event or a major trauma code. Without this behind-the-scenes logistical orchestration, frontline clinical excellence is severely compromised. By embracing these administrative challenges, anaesthesia leaders can secure the funding and equipment their teams need to deliver excellent care. This form of upward leadership involves influencing hospital CEOs and board members to recognise that anaesthesiology is not a cost centre, but a major driver of surgical productivity and hospital safety. When anaesthesiologists lead at this level, they protect the entire surgical service from the negative impacts of uninformed administrative decisions.

Professional resilience is another key theme that ties together clinical care and administration. High-performing teams are those where the leader proactively manages the workload and provides emotional support to their staff. In a field as demanding as anaesthesiology, the risk of fatigue and burnout is ever-present. In the specific context of high-acuity trauma care, where clinical teams frequently face emotionally taxing, life-or-death scenarios with unpredictable hours, team resilience is not merely a personal trait but a crucial systemic safeguard. A burnt out team is significantly more prone to cognitive fixation errors and communication breakdowns, which can prove fatal during a complex, fast-paced trauma resuscitation. Leaders must implement systems that encourage rest, peer support, and professional growth. This is not just a kind gesture; it is a critical administrative strategy to maintain the quality and safety of patient care. A resilient workforce is a more productive and safer workforce. By prioritising the well-being of their colleagues, anaesthesia leaders ensure that the department can consistently meet the high demands of a modern surgical hospital. This requires a shift in mindset from a purely clinical focus to a more holistic view of the anaesthesia care team as a human system.

10.8 Conclusion

The synthesis of research and guidelines shows that effective leadership in anaesthesia is a relational, adaptive, and deeply human process. It requires us to move beyond the technical mastery of the past and embrace a more comprehensive, systems-oriented approach to care. By choosing transformational and authentic styles, we can build teams that are both strong and resilient. The integration of organizational change models, like those of Weisbord, Bridges,

and Kotter, allows us to navigate the institutional challenges of modern healthcare with confidence. Whether we are managing a routine surgery, a life-threatening trauma, or the administrative complexities of a large hospital department, anaesthesia leaders in Malaysia continue to play an infinite game. This is a journey driven by a relentless pursuit of safety, professional integrity, and the best possible care for every patient. It is a role that demands not only a brilliant mind and steady hands, but also a compassionate heart and a courageous spirit. Through the combination of clinical excellence and administrative leadership, we ensure that the specialty of anaesthesiology remains at the very heart of the modern healthcare team, consistently delivering the safe and effective care that all Malaysians deserve.

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Collaborative Practice in Anaesthesia: Strengthening Teamwork Through Leadership and Simulation

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KEY POINTS

- Effective teamwork is essential for safe perioperative care, particularly in the high-risk, time-sensitive environment of anaesthesia.
- Leadership is a critical human factor that influences team coordination, communication, and patient safety.
- The Big Five Model of Teamwork consists of leadership, situational awareness, team orientation, adaptability, and backup behavior.
- Simulation-based training strengthens technical skills, crisis resource management, and multidisciplinary collaboration.
- Integrating regular multidisciplinary simulation into anaesthesia training and clinical practice can improve perioperative outcomes and quality of care.

Keywords: Teamwork, collaborative practice, simulation training.

11.1 Introduction

Effective teamwork within anaesthesia teams and across multidisciplinary healthcare professionals is essential for optimal patient care. Team members often have differing perspectives on what constitutes good teamwork, and individual needs and priorities may vary, particularly during situations of crisis.[1] Numerous strategies have been recommended to improve perioperative patient safety; however, leadership remains one of the most critical factors. Among the key human factors influencing teamwork are leadership and coordination.[1]

11.2 The Big Five Model

To achieve effective teamwork, the Big Five model of teamwork identifies five core components, supported by coordinating mechanisms such as shared mental models, closed-loop communication, and mutual trust:[2]

- (a) **Leadership** — The ability to direct and coordinate team activities, assign roles, monitor performance, and continuously update team knowledge.[2]
- (b) **Situational awareness** — Ensuring that the team maintains a shared understanding of the clinical situation, particularly during crises, and is able to implement appropriate strategies to resolve problems.[2]
- (c) **Team orientation** — Recognizing and valuing each member's strengths, considering the opinions of teammates, and appropriately appraising their contributions.[2]
- (d) **Adaptability** — The capacity to adjust rapidly to dynamic clinical situations, including reallocating resources and redistributing workload as needed.[2]
- (e) **Backup behavior** — Anticipating the needs of other team members through a clear understanding of their roles and responsibilities, and providing support by shifting tasks when necessary.[2]

A cross-sectional study carried out in Malaysia, with the aim to examine the factors associated with speaking up and withholding the voices among healthcare workers, discovered that staff working in emergency and intensive care departments, junior staff, and those who worked at lower hierarchical levels were less likely to voice out.[3] Also, healthcare workers were less likely to voice out in a discouraging environment.[3] However, speaking up is a crucial component of effective teamwork and patient safety. Encouraging team members to contribute requires explicit invitation and genuine appreciation from leaders—a concept referred to as leader inclusiveness.[1]

11.3 Dynamic Nature of the Anaesthesia Team

Anaesthesia teams operate in high-intensity, time-pressured environments where rapid decision-making and effective coordination are essential for patient safety. Multiple factors contribute to cognitive overload and workplace stress, including collaboration with various primary teams, conflicting surgical priorities, complex interpersonal dynamics, and pressure to maximise operating theatre efficiency.[1] Frequent interruptions, unpredictable adverse events, rapid physiological changes, and unforeseen surgical complications further compound these challenges. Additionally, workflow disruptions and variable team compositions increase the complexity of perioperative care delivery.[1] In such environments, effective coordination and leadership are critical determinants of patient outcomes.

Team coordination can be broadly categorised into explicit and implicit forms. Explicit coordination relies on direct communication and clear task delegation, whereas implicit coordination depends on shared mental models among team members.[1] While anaesthesia teams frequently rely on implicit coordination due to routine practice and familiarity, this approach may become ineffective and potentially unsafe when team members do not share the same mental model.[1] In crisis or highly complex scenarios, explicit coordination becomes particularly important to realign shared understanding, prioritise tasks, and ensure effective task execution.[1] Simulation studies have demonstrated that teams perform more effectively when practising shared leadership and adapting coordination strategies to situational demands, resulting in improved preparedness for real clinical events.[4]

11.4 Simulation Training for Perioperative Care

Despite the importance of these competencies, formal leadership and coordination training during postgraduate anaesthesia education in Malaysia remains limited. Although trainees receive comprehensive instruction in perioperative care, anaesthesia crisis management, and disease-specific anaesthetic considerations, leadership and teamwork skills are often acquired informally through observation of senior colleagues. In some cases, trainees may manage cases or perform procedures for the first time without prior structured simulation experience, potentially increasing risks to patient safety. Furthermore, during crisis situations, discrepancies in shared mental models are frequently observed among specialists, junior medical officers, and general anaesthesia assistants. Although weekly continuing medical education (CME) sessions are conducted, structured multidisciplinary crisis

simulation opportunities remain insufficient.

Simulation-based education offers a systematic approach to addressing these gaps. It enables learners to gain experience in rare but critical clinical events, practise interprofessional coordination, and standardise educational exposure before interacting with real patients.[4] There are some strategies to close the gap, such as having a standardised manual, systematic education on core concepts, simulation-based education, and detailed debriefing after simulation scenarios.[5]

For example, healthcare teams often demonstrate stronger performance in cardiac arrest management compared to anaphylactic shock in the operating theatre, possibly due to the mandatory Basic Life Support (BLS) training that incorporates simulation exercises. A study conducted in India by Kanwalpreet S et al. to evaluate the efficacy of BLS and advanced cardiac life support (ACLS) courses on the outcomes of CPR showed higher return of spontaneous circulation and higher survival to hospital discharge in the post-courses training period ($p < 0.005$).[6] Similarly, simulation training for obstetric emergencies such as postpartum haemorrhage, amniotic fluid embolism, and eclampsia is more routinely conducted within obstetric departments to enhance preparedness and clarify team roles.

Simulation-based education is broadly divided into technical and non-technical domains.[7] Technical skills training focuses on improving procedural competence, psychomotor abilities, and applied medical knowledge, such as the use of various airway adjuncts in managing difficult airways.[7] Non-technical skills training emphasises situational awareness, task management, planning, teamwork, decision-making, and communication.[7] Expanding simulation-based education within anaesthesia departments to include specialists, medical officers, and general anaesthesia assistants may strengthen crisis resource management and improve patient outcomes.

Interprofessional simulation represents another important training modality, incorporating healthcare professionals from different disciplines to conduct team-based exercises aimed at refining protocols and identifying system vulnerabilities.[7] Such training promotes a culture of patient safety by reinforcing team familiarity, defining roles and responsibilities, and encouraging open communication to reduce medical errors.[7] An extensive review by the U.S. Department of Health and Human Services' Agency for Healthcare Research and Quality (AHRQ) recommended the integration of team training and simulation training in healthcare systems.[8] The TeamSTEPPS intervention has been associated with significant reductions in medication and transfusion errors.[8] Furthermore, Mark LJ et al. evaluated the Difficult Airway Response Team (DART) programme over five years, demonstrating positive changes in patient outcomes, including reductions in airway management-related

mortality and malpractice claims.[9] Participants also reported favourable feedback regarding the value of simulation-based training.[9]

Although implementing comprehensive simulation programmes in resource-limited settings presents logistical and financial challenges, existing evidence supports their effectiveness in improving leadership, teamwork, and patient safety outcomes. Integrating structured team training and simulation into postgraduate anaesthesia curricula may therefore address current gaps in leadership and coordination competencies, ultimately enhancing perioperative safety and patient care quality.

11.5 Communication and Teamwork with Surgeons

The operating theatre (OT) environment is the most complex and volatile workplace, where two contemporary physicians, the surgeon and the anaesthesiologist, share the responsibility of one patient. Decades ago, the anaesthesiologist was considered the surgeon's assistant. The anaesthesiologist's position has slowly evolved from a behind-the-scenes speciality to an independent specialty with the immense development in the anaesthesia field throughout the years. Despite so, in developing countries such as Malaysia, the role of the anaesthesiologist in the successful outcome of surgery is not acknowledged by the public. The surgeon is respected as the primary physician, while the anaesthesiologist is considered a consultant who is asked to participate in the peri-operative care of the patient.[10] The lack of acknowledgement of the role played by the anaesthesiologist both inside and outside of the OT, the lack of appreciation from the surgeon, and poor social interaction with the patient reduce the self-esteem of an anaesthesiologist. Variation in opinions, values, experience, interests, and knowledge between the surgeon and anaesthesiologist may arise while working in the high-pressure environment like the OTs, which may lead to the occurrence of a conflict.[11, 12] These differences are seen more prominently amongst the surgeon and the junior anaesthesiologist.

Many anaesthesiologists encounter unique challenges in their way of achieving professional identities. The lack of mutual professional respect and understanding is also observed among the anaesthesiologists and other personnel working in the OTs. It is inevitable to see this situation in Asian countries where seniority, hierarchy, and power imbalance are the main reasons for the creation of an unhealthy working environment, which will further compromise the self-confidence and performance in the journey for individual development of the junior anaesthesiologists.[13]

Differences in opinions are normal, as two individuals who are from different backgrounds cannot be expected

to agree on everything all the time. To create a healthier and relatively amicable working environment, all of us need to play a part to achieve it. Constantly working in high-pressure environments makes conflicts likely—and one should anticipate, identify, and comply with local guidelines or policies available, which may be helpful in resolving some of the conflicts. When dealing with such scenarios, one should remain non-judgmental throughout the discussion and take all relevant factors into consideration. Maintaining good communication skills is another crucial point. Both teams should always keep calm and listen to the other to understand the concerns from each side to come up with the best solution for the patient.[10] However, when the situation gets out of control, it would be prudent to avoid conflict in public and to aim for resolution in a professional manner. Always remember, our responsibility as the treating physician is to deliver the best treatment for the patient in their best interests while working as a team.

11.6 Collaborative Efforts in Perioperative Care: National Initiatives Driving Safer Surgery in Malaysia

The Ministry of Health (MOH) has taken effective initiatives over the decades to improve patient safety by enhancing perioperative teamwork. One of the best approaches is the establishment of the Safe Surgery Saves Lives (SSSL) guideline, second edition, which was released in 2018. One of the main objectives of the guideline is to improve communication and teamwork to ensure safer surgery.[14] The use of this guideline acts as a catalyst in improving patient safety by promoting continuous communication between the staff from the pre-operative period to the post-operative period, from the ward to the operating theatre and then back to the ward. This guideline helps to close the gaps between the surgeons, the anaesthetists, the nurses, and the patients.

Moreover, the government also developed the National Policy for Quality in Healthcare (NPQH) with the intention to deliver high-quality care for the people. One of the three main core values mentioned is teamwork, which could be achieved by the collaboration and engagement of effective communication between the ministries, programmes, healthcare workers, patients, and family.[15]

Recently, the Malaysian Perioperative Medicine Society (MPOM) was established, and the first symposium was held in early 2025, which brought professionals from multiple disciplines together to share the latest updates for educational purposes and also for better rapport in order to enhance the teamwork among healthcare workers from different disciplines. It was

organised by the MPOM with close collaboration with the Malaysian Society of Hepato-pancreato-biliary Surgeons (MyHPBS) and the Malaysian Society of Regional Anaesthesia (MySORA). The theme of the symposium focused on enhancing patient recovery through multidisciplinary excellence, which included speakers from Anaesthesiology, the Emergency Department, Medical Physicians, and Surgeons.

11.7 Conclusion

Anaesthesia practice occurs in complex, high-risk, and time-sensitive environments where patient safety depends not only on technical expertise but also on effective teamwork and leadership. While postgraduate training programmes provide comprehensive clinical knowledge and procedural skills, structured education in teamwork, crisis resource management, and interprofessional coordination remains insufficient. Given the dynamic and unpredictable nature of perioperative care, these non-technical competencies are essential rather than optional.

Although national-level simulation workshops have contributed to improvements in both technical and non-technical skills, broader implementation of regular, department-based simulation training is warranted. Integrating multidisciplinary simulation programmes that involve specialists, medical officers, general anaesthesia assistants, and nurses would strengthen shared mental models, clarify team roles, and enhance crisis preparedness.

Incorporating structured teamwork and simulation-based training into postgraduate curricula—and sustaining it as part of lifelong professional development—represents a strategic investment in patient safety. Expanding such initiatives at the departmental level may bridge existing gaps in leadership and coordination competencies, ultimately improving perioperative outcomes and the overall quality of anaesthesia care.

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Prehabilitation in Major Surgical & Oncological Surgeries – A Reflection on Current Practices

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Abstract

Prehabilitation is an evolving concept that must be embraced by the forward-thinking surgeon and anaesthesiologist, as key stakeholders in the journey of perioperative medicine. This article explores the history of prehabilitation and current scalable models for adaptation in Malaysia, citing the inpatient prehabilitation in Japan and the pre-admission clinic (PAC) in Singapore.

The article expands on the role of the surgeon and the anaesthesiologist, defining the need for collaborative practice. The surgeon and the anaesthesiologist are not running separate races toward separate finish lines, but neither are we always running at the same pace. The surgeon's clock, set by the tumour biology and the risk of disease progression, often moves faster than the anaesthesiologist's clock, which is set by how much physiological reserve can be genuinely built in the time that remains. Running the same race at a variable pace is not a failure of coordination; it is what complementing each other actually looks like in practice.

12.1 Introduction

The legendary founder and industrialist, Henry Ford, was famously quoted for his wise words: “Coming together is a beginning; keeping together is progress; working together is success.” This theme strongly resonates with the endeavours of the surgical team as they plan for major oncological surgeries. A good and experienced surgeon knows that the outcome of the surgery transcends surgical precision. Essentially, it is the culmination of everything that is done before, during and after a surgery, and good post-operative outcomes starts with thorough pre-operative preparation. The future-ready anaesthesiologist shares this vision and warms to the idea of adopting scalable perioperative models in their respective institutions. Ultimately, working together and understanding each other’s perspectives leads to positive outcomes for the most important person in the equation, i.e. the patient.

12.1.1 The History of Prehabilitation

Interestingly, ‘prehabilitation’ was a concept first described in 1946 when a group of young military recruits were physically and mentally conditioned with vigorous physical and psychological training prior to entering full-fledged military service.[1] We can see a striking familiarity with the assimilation of this word in clinical practice. An unfit patient is less likely to experience a favourable outcome after a major surgery, necessitating prehabilitation for optimal readiness.

In the early 2000s, the concept of prehabilitation gained traction after being introduced by Topp et al.[2] The goal was clear, i.e. to improve the functional reserve of patients prior to surgery, enhance post operative recovery and improve the patient’s quality of life.

It has only been less than a decade (i.e. 2020) since the introduction of the bundle of prehabilitation elements based on evidence-based medicine.[3] Subsequently, the concept of enhanced recovery after surgery (ERAS) became a widely applicable practice.

12.1.2 Scalable Models of Perioperative Medicine

With the evolving landscape in perioperative medicine, the collaboration between the surgeon and the anaesthesiologist is very much advocated. Current data place perioperative mortality as the third leading cause of death after heart disease and malignancy, worldwide.[4] This has beckoned the need for a greater partnership to reduce post-operative morbidity and mortality.

In Singapore General Hospital, the pre-admission clinic (PAC) has become a one-stop clinic that integrates a multidisciplinary consultation in a single loop, with an average of 100 to 110 patients a day. This consists of stations for the anaesthesia

assessment, internal medicine perioperative clinic, preoperative physiotherapist and dietician assessments, nurse counselling for specific surgical programmes, intravenous iron therapy suites as well as a financial counselling unit.[5] This model has proven to be an efficient pathway in establishing a prehabilitation workflow.

12.1.3 The Role of the Surgeon

The surgeon is the vanguard of early risk stratification and identification of the ill patient, even before a tentative surgery. Thus, the prehabilitation journey is crucially established upon the initial screening and diagnosis of an operable surgery.

In Malaysia, the importance and subsequent implementation of an organized, thorough, and comprehensive prehabilitation programme has yet to be fully embraced by all surgical teams. It is practiced sporadically, depending on the background of training any one particular surgeon may have. Certain units emphasize it rigorously and have well-established prehabilitation protocols, whilst others may not. The surgeon plays a key role as they are the primary health care providers for these patients, and take on the final responsibility for the outcome of a patient’s procedure.

In an age that leans towards value-based healthcare, admitting a patient prior to surgery to facilitate prehabilitation may appear to increase the workload of staff and stretch resources. One may wonder if these interventions could be done at the comfort of the patient’s home with a guideline given to the patient. However, we observe that in-patient admission allows for a better structured and monitored prehabilitation pathway in a select group of patients. Furthermore, admitting patients for prehabilitation allows the teams to engage the help of Sports Medicine physicians and physiotherapists who have specific training in increasing functional capacity and reserve of individuals preparing for major surgery. Admitting patients allows access to a well-equipped gymnasium and a structured, monitored programme by the very doctors who have training in this area.

A small study in Malaysia involving 31 patients observed improved postoperative outcomes amongst gastric or oesophageal cancer patients recruited to undergo 2 weeks inpatient prehabilitation programme.[6] In developed nations like Japan, the advocacy for prehabilitation for major gastric and oesophageal carcinomas remains strong.[7] For instance, a study done in 2025 in Japan highlighted that there were 77 facilities providing prehabilitation for esophagectomy, of which 45% of these facilities provided inpatient prehabilitation programmes. Suffice to say, these practices are well received and practiced worldwide.

12.1.4 Collaboration with Anaesthesiologists: Running the Same Race

Surgery, at its heart, is a marathon and not a sprint. Long before a patient finds their way to the starting line of the operating theatre, they must arrive with a certain level of fitness, nutritional reserve and mental readiness if they are to successfully cross the finish line. The goalpost of the desired outcome may vary. Broadly, every patient and clinician will desire for patients to have their life intact, recovered and back to their baseline when possible. Along this course lies obstacles we can plan for and obstacles we cannot fully anticipate. It is often hardest to ‘control’ the patient’s own body. This includes the comorbidity that has quietly progressed for years, the sarcopenia that has crept in unnoticed, and a depleted physiological reserve. This is a precise terrain in which prehabilitation becomes fundamental.

In the Malaysian setting, this course is frequently shortened before it has even begun. A meaningful proportion of our patients present late, often with locally advanced or a marginally resectable tumour. At this point, the oncological clock is running fast and the luxury of a leisurely and extended prehabilitation window is rarely available to us. Time-sensitive surgery shortens the very runway that prehabilitation depends on. This is not a reason to abandon the endeavour. It is a reason to be honest about what “training” for the marathon can realistically look like when we have days rather than months, making each day a significant milestone for the patient.

It is worth saying plainly, as a perioperative physician: prehabilitation should not be understood merely as an extension, or a supplementary add-on, to conventional preoperative optimisation. Optimisation addresses whether a patient is fit enough to proceed for surgery. Prehabilitation requires something more ambitious of us; whether we can actively build the endurance and resilience a patient needs to absorb the stressor that major surgery represents, and to recover from it well.

Surgical injury elicits a genuine physiological stress response, one that catabolises a patient’s energy and protein reserves in the process of healing. Surgical resilience on the other hand is a patient’s capacity to withstand that stress, and to return to homeostasis afterward.[8] Prehabilitation is how we help build that reserve before the demand is placed upon it, in the same deliberate way a runner conditions their body months before race day.

The case for surgeon-anaesthesiologist collaboration is well established, and models such as Singapore General Hospital’s one-stop PAC demonstrates what that partnership can look like once it is built into the system itself, rather than left to individual goodwill. Anaesthesiologists now sit alongside our surgical colleagues from the earliest point of referral, not simply at the pre-admission days before surgery.[9]

With that overview, how do we strengthen this particular partnership so that it serves the patient rather than duplicating, or worse, leaving gaps in each other’s efforts?

The answer, in our experience, lies in genuine complementary work-based partnership. Where one of us has less expertise, resource or bandwidth, the other should be willing and ready to step in, in whichever domain we are best placed to lead. The surgeon owns the oncological clock; the urgency of diagnosis, staging and the window within which surgery must reasonably occur. The anaesthesiologist owns the physiological clock; risk stratification, functional capacity testing, medical optimisation of comorbidities, nutritional and anaemia correction, and preparation of the patient’s mind for what lies ahead. Neither of these clocks runs independently of the other. In instances when our responsibilities overlap, as they inevitably do in nutrition screening, patient education and goal-setting, that overlap should be a deliberate, shared space rather than an accidental one.

This is why transparency between us matters as much as competency within our own fields. Assumptions are the quiet saboteurs of good perioperative care. A structured, honest handover, joint clinics where feasible, and a shared documentation of the patient’s goals of care can close that gap. Prehabilitation succeeds not because one specialty does more, but because both specialties know precisely what the other has done, is doing and still needs to do.

At the centre of all of this sits the patient, and it is here that shared decision-making becomes indispensable rather than aspirational. Surgeons in particular have shown themselves willing to postpone surgery, when clinically appropriate, to allow prehabilitation to run its course if it meaningfully reduces the risk of postoperative complications and improves the odds of completing planned adjuvant therapy. But that decision should not be made in isolation but rather with the inclusion of the patient and their next-of-kin. The risk stratification data should be shared openly and a realistic account of what prehabilitation can and cannot promise must be made transparent.[9, 10] We must resist the temptation to oversell prehabilitation as a guarantee of a better outcome. The evidence, while encouraging, is still maturing, and patients deserve our honesty about that uncertainty as much as they deserve our optimism.[10]

When the surgical timeline is compressed by late presentation or disease urgency, our role shifts from lengthy conditioning to rapid, targeted optimisation: correcting anaemia in days rather than weeks, prioritising the one or two modifiable risks that matter most for that particular patient, rather than insisting on the full multimodal programme regardless of the runway available. When the timeline allows, we lean fully into the endurance-building work that prehabilitation was designed for. Either way, our collaboration is only as strong as our willingness to

be transparent with one another about how much time we truly have, to complement rather than compete, and to keep the patient's own voice at the centre of every decision we make on their behalf. When the partnership works as it should, the patient stops experiencing prehabilitation as a relay between disconnected teams, and starts experiencing it as what it was always meant to be: one team, adjusting the pace together, running the course beside them.

12.1.5 Nutritional Prehabilitation: Optimizing Metabolic Reserve

In the preoperative period, it is most crucial that nutritional risk and sarcopenia are identified early using validated screening metrics. Clinicians must familiarize themselves with current, standard assessment tools, most notably the Nutritional Risk Screening 2002 (NRS-2002) and the Malnutrition Universal Screening Tool (MUST).[11]

Rather than relying on isolated metrics, risk stratification must account for all independent risk factors for postoperative complications, which include:

- Severe preoperative weight loss
- Decreased oral intake
- Sarcopenia (loss of muscle mass and function)
- Extreme Body Mass Index (BMI) deviations (both severe thinness and sarcopenic obesity)

While the surgeon initiates these risk assessments at the time of initial consultation, the anaesthesiologist can co-manage the nutritional aspects of the prehabilitation journey. After identification of a nutritionally at-risk individual, nutritional rehabilitation must be initiated in a structured, step-wise manner. Current literature has also shown us that nutritional rehabilitation should take between 10–14 days. If it is less than 10–14 days, the benefits may not be seen. Beyond this time frame, any further benefit is unlikely to be achieved as the pathological clock that is stressing the patient's physiology, continues to tick. Hence, if rehabilitation cannot be achieved within 2 weeks, further rehabilitation is likely futile and a decision should be made on whether the patient may benefit from surgery or not.

The anaesthesiologists must also look into immediate preoperative medications like sodium-glucose cotransporter 2 inhibitor (SGLT-2), and period of fasting leading up to the surgery.

Studies have shown that administration of a dextrose containing solution the night before selected abdominal surgery decreases protein catabolism, insulin resistance, and fat oxidation. This may directly improve postoperative metabolism via attenuation of cortisol and glucagon release.[12]

12.1.6 Preoperative Exercise and Physiological Conditioning

Several modalities exist to assess cardiopulmonary function using available hospital resources like the cardiopulmonary exercise test (CPET) or a 6-minute walking test (6MWT). A pulmonary function test is also of value especially in certain cohorts of patients that may require lung isolation or prolonged ventilation. The 6MWT is a simple, highly-validated test that gives valuable information on a patient's cardiopulmonary function. It has been shown that a 6-minute distance of 454m directly correlates to a reduced post-operative complication rate.[13] Should a more thorough assessment be required, then a CPET or a dobutamine stress test, both of which tests the patient's cardiac response to stress, can be initiated.

Adapted physical exercises are highly individualized and prescribed with the goal of increasing muscle strength, cardiorespiratory fitness, and overall well-being. Aerobic exercise preoperatively increased VO₂ max by 15% and reduced postoperative pulmonary complications by 20% in patients undergoing oesophageal resection.[14] The aerobic exercise and interval muscle training also shows reduced overall morbidity rate compared with no specific training.[15]

12.1.7 Medical Optimization and Risk Mitigation

The anaesthesiologist plays a pivotal role in medical optimization of co-morbidities. Apart from remediation of medications and lifestyle modification like smoking and alcohol cessation, addressing preoperative anaemia is an important part of prehabilitation and patient blood management. In time-sensitive surgeries, multidisciplinary input may be required to balance time for optimizing health conditions and risks of delaying the procedure. Open communication with the patient at the centre of the discussion is key.

An evolving practice in the fraternity is optimizing iron deficiency anaemia prior to major surgeries. The ALICE study demonstrates a high prevalence of preoperative anaemia, which is an independent risk factor for severe outcomes. Iron deficiency is the leading cause of anaemia. However, the prevalence of vitamin B12 and folate deficiency among anaemic patients is also substantial. When available, the administration of intravenous iron therapy in time sensitive surgeries appears to have significant benefit.[16]

12.1.8 Empowering the Patient's Mindset

Prehabilitation is too often framed solely as something that is done to a patient: an exercise plan prescribed, a nutritional target set, a supplement dispensed. Yet the psychological dimension of prehabilitation, arguably the hardest to measure and the easiest to neglect, may determine whether any of the above is

followed at all. Preoperative anxiety, depression and fear are consistently associated with worse surgical outcomes, including greater anaesthetic requirements, more postoperative pain, and slower return to baseline function.[8] A patient who does not understand why they are being asked to walk further, eat differently, or delay a surgery they were told was urgent, is unlikely to commit to any of it.

The period between diagnosis and surgery has been described as a “teachable moment”: a window in which patients, confronted with the seriousness of their illness, may be unusually receptive to changing long-standing habits.[10] We should use this window, but use it honestly. The teachable moment is not a guarantee, and it is mediated heavily by a patient’s health literacy, language, cultural background and social support, all of which vary considerably across our multi-ethnic, multi-lingual patient population. Communicating prehabilitation well means more than handing over a pamphlet; it means explaining, in the patient’s own language and at their own pace, what surgery will demand of their body, what prehabilitation offers in return, and what remains genuinely uncertain.

This is where shared decision-making earns its place, not as a slogan, but as daily practice. Involving next-of-kin and caregivers, screening for distress using simple validated tools, and setting goals collaboratively rather than prescriptively, all reinforce a patient’s sense of agency at a time when illness has taken so much of it away. An empowered patient is not simply a more compliant one; they are a partner who understands the race they are running, and why they have chosen to run that race.[9]

12.1.9 Challenges in Implementation

Translating prehabilitation from published trial to routine practice in Malaysia is not without friction. Several challenges deserve honest acknowledgement.

Time. As discussed above, many of our patients present with locally advanced disease, leaving a narrow window between diagnosis and surgery. Multimodal programmes designed and tested over four to six weeks are difficult to deliver when the realistic runway is closer to one or two.

Resources and workforce. A structured inpatient prehabilitation pathway requires dedicated surgeons, physiotherapists, dietitians, sports medicine physicians, and psychological support staff working in a coordinated fashion, resources that are not equally distributed across centres, and that compete with the day-to-day demands of a busy tertiary unit.

Awareness. Even where services exist, referring clinicians and patients alike may simply be unaware of them, or unclear on referral criteria, echoing findings from healthcare systems abroad where prehabilitation services were found to be underused because staff did not know they existed.[10]

Local evidence. The Malaysian evidence base remains nascent; our own single-centre experience of 31 patients[6] is encouraging but far from sufficient to guide practice across our diverse population, and larger, locally relevant studies are needed before we generalise findings from Western or East Asian cohorts to our own patients.

Equity of access. Perhaps the most important, and least discussed, challenge is the risk that prehabilitation, if implemented without care, benefits only those patients who already have the resources, mobility, health literacy and social support to engage with it, potentially widening rather than narrowing the gap in outcomes between our patients.[16] Inpatient programmes may partially mitigate this by removing the burden of travel and cost, but they introduce their own considerations, including infection control precautions in a shared hospital environment and the opportunity cost of inpatient bed occupancy.

Overlap of care. Finally, as raised above, without clear and transparent delineation of roles between surgical and anaesthetic teams, prehabilitation risks becoming everyone’s responsibility and therefore no one’s, underscoring the importance of structured, documented collaboration rather than goodwill alone.

12.2 Looking Ahead

Despite these challenges, we remain hopeful. Our aspiration is for prehabilitation to move from a series of individual, well-intentioned efforts into a structured, institutional pathway: one with clear referral criteria, a shared multidisciplinary clinic, and standardised outcome measures that allow us to build a genuinely Malaysian evidence base rather than borrowing entirely from elsewhere. Models such as the one-stop PAC described above offer a template we could adapt locally, bringing anaesthesia assessment, physiotherapy, dietetics, nurse counselling and even financial counselling into a single patient journey, rather than the fragmented series of appointments many of our patients currently navigate. We hope to see closer integration between prehabilitation and our existing ERAS protocols, so that preparation and recovery are understood as a single continuous journey rather than two separate programmes.

We also see real promise in technology-assisted and home-based models, particularly for patients for whom travel, cost, or time genuinely precludes an inpatient stay, provided these are designed with digital exclusion and equitable access in mind, rather than as a cost-saving afterthought. National guidance, similar to that developed by the Royal College of Anaesthetists and Macmillan Cancer Support in the United Kingdom, would go a long way toward standardising practice and securing the institutional support prehabilitation needs to thrive locally.

None of this, however, will succeed without the continued willingness of surgeons and anaesthesiologists

to keep working as one team rather than two. If this article achieves nothing else, we hope it leaves the reader with the same conviction that has shaped our own collaboration: that prehabilitation is not a checklist to complete before surgery, but a shared commitment to giving every patient the fitness, the reserve, and the mindset to finish the race we have asked them to run.

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Part III

Smart Technology

Future-Ready Anaesthesia Training: Integrating Digital Technologies Into Programme Governance

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Abstract

Malaysia currently has a growing number of practising anaesthesiologists, but the demand for specialist services continues to outpace supply as surgical and critical care services expand nationwide. As training programmes develop to address this need, effective programme governance becomes increasingly important to ensure consistent supervision, competency development and quality assurance. However, governance activities are often managed by a limited number of academic staff, who rely on manual documentation systems. This article shares how simple digital technologies can support programme governance in anaesthesia training at the International Islamic University Malaysia (IIUM). Practical tools such as learning management systems, digital logbooks, data dashboards and automated reminders can improve monitoring of trainee progression while reducing administrative workload.

13.1 Introduction

As of early 2025, Malaysia has more than 600 practising anaesthesiologists,[1] the majority of whom are trained through master's programmes at local universities, with others completing recognised parallel pathways. While this reflects steady progress in building the nation's anaesthesia workforce, the demand for specialist care continues to grow. Current projections estimate that an additional 1123 anaesthesiologists will be required to meet the needs of expanding surgical and critical services.[1] This gap underscores the importance of strengthening and expanding anaesthesia training programmes while exploring innovative approaches to support the next generation of specialists and sustain high-quality perioperative care.

As this momentum builds, a new challenge comes into focus: scaling up trainee numbers also means rethinking how programmes are governed. One major hurdle remains: the shortage of trainers. In a competency-based training model, no digital tool, no matter how advanced, can replace the human touch needed to shape a trainee's knowledge, technical skills, and professional values.[2]

Even so, technology plays an important supporting role. While it cannot replace the trainers, it can certainly enhance teaching and learning. Today's trainees are increasingly digital natives, and their learning preferences have naturally shifted towards digital-first platforms and tools. When used wisely, these innovations can help lighten the load, enrich learning experiences and support trainers as they guide the next generation of anaesthesiologists.

13.2 Programme Governance

While teaching and learning may be the most visible part of any training programme, what happens behind the scenes is just as crucial and often easy to overlook. Programme governance provides the structures, processes, and decision-making mechanisms that keep the programme organised, safe and purposeful, from day-to-day teaching activities to long-term planning and improvement.

At the heart of governance lie several core components that keep the training experience coherent and consistent. Curriculum oversight ensures that what is taught remains current and clinically relevant. Trainee monitoring helps track progress and identify those who may need additional support. Supervision and mentorship provide the human connection that guides trainees through their most formative years. Well-designed assessment and feedback systems offer structured opportunities for growth, while quality assurance processes and accreditation requirements safeguard the programme's credibility and standards. Together, these elements form a coordinated ecosystem that upholds the integrity of anaesthesia training.

Strong governance matters because it directly

influences what ultimately counts most: patient safety, trainee competency, and the programme's accountability. When all components function well, trainees receive consistent guidance, assessments are meaningful, and patients experience safer, more reliable care. It ensures that the programme isn't just producing specialists, but producing specialists who are ready for the demands of real-world practice.

13.3 Governance Challenges in Real-World Training Programmes

Behind every training programme is significant work that goes unnoticed. Programme governance requires continuous monitoring of trainee progress, documentation of clinical exposures, coordination of assessments and preparation of reports.[3] In reality, much of this work is handled by a small number of academic staff, sometimes with limited administrative support. Lecturers who are already balancing clinical service, teaching and research responsibilities frequently find themselves managing logbooks, collecting assessment forms and compiling data for programme meetings or accreditation exercises.

As training programmes expand to meet the country's growing demand for anaesthesiologists, the number of trainees continues to increase. While this is a positive development for the healthcare workforce, it also means that monitoring trainee progression becomes more demanding. Programme coordinators must ensure that each trainee receives adequate clinical exposure, completes competency assessments and progresses through training milestones. At the same time, trainees often rotate across multiple hospitals and clinical units, working with different supervisors throughout their training. Maintaining continuity in supervision and tracking trainee development across these rotations can be challenging, particularly when documentation relies on manual records or paper logbooks.

13.4 Small Digital Solutions That Make a Big Difference

Strengthening programme governance does not always require complex systems or expensive software. In many cases, simple digital tools that are readily available can already make a meaningful difference. Platforms that lecturers are familiar with, such as learning management systems, shared online documents, digital forms and basic data dashboards, can be adapted to support many governance tasks. These solutions are often low-cost or already available within institutional ecosystems, making them more practical and sustainable in the long

term. By thoughtfully combining these accessible technologies, programme coordinators can streamline documentation, improve communication and gain clearer visibility of trainee progression without the need for large investments in specialised platforms.

Although the examples described are based on the IIUM setting, several principles are applicable across training programmes. Digital tools should be selected according to local needs, available resources and existing institutional systems. Programmes may begin with simple, low-cost platforms before progressing to more integrated solutions. Clear roles, consistent data entry, staff training and regular review are also important to ensure that the technology supports governance without creating additional administrative burden. Most importantly, digital systems should complement, rather than replace, clinical supervision and professional judgement.

13.4.1 Learning Management Systems

Learning management systems (LMS), often built on platforms like Moodle, have become central hubs for structured learning in many training programmes. At the International Islamic University Malaysia (IIUM), the iTa'LeEM platform hosts learning resources, lecture notes, recorded lectures, case discussions and multimedia content in a single, organised environment. At the same time, built-in analytics allow lecturers to monitor participation, track activity completion and review quiz performance. Features such as online quizzes, formative assessments and discussion forums also support flipped-classroom approaches, which are particularly suitable for adult learners like clinical trainees who often balance learning with demanding clinical duties.

Trainees can access these materials after clinical hours, revisit complex topics at their own pace, complete online quizzes and participate in discussion forums. This flexibility supports self-directed and flipped learning, particularly for clinical trainees who must balance education with demanding clinical duties.

From a governance perspective, LMS platforms also benefit programme coordinators and administrative staff. Routine academic tasks, such as sharing announcements, collecting assignments or monitoring assessment completion, can be managed within the system. Automated records of participation and assessment results provide useful documentation for programme monitoring and accreditation.

13.4.2 Digital Logbook and Competency Tracking

One major limitation in traditional training systems is the continued reliance on paper-based logbooks to document clinical exposure and procedural competence. Such systems often rely on retrospective documentation and periodic review, in which trainees

may record procedures only at the end of a posting or during scheduled evaluations.[4, 5, 6, 7] This approach increases the risk of incomplete or inaccurate records and makes it difficult for supervisors to obtain a timely overview of trainee progress.[8]

Digital logbooks address this limitation by enabling real-time data entry, allowing trainees to record clinical procedures and learning activities immediately after they are performed. Real-time documentation improves the accuracy and completeness of records while providing supervisors and programme coordinators with continuous visibility of trainee exposure and competency development.[6, 7] One simple way to implement this is through online forms, where trainees submit procedure details using a structured digital form on their mobile devices after each case. The submitted entries are automatically compiled into a spreadsheet database, removing the need for manual data entry. For example, trainees may complete a short online form that captures the type of procedure, level of involvement, and the supervising specialist or consultant. The responses are then stored in a central spreadsheet, which can be analysed using simple formulas or dashboards. With basic automation, the spreadsheet can highlight trainees who have not achieved adequate case volumes or certain procedures, allowing supervisors to identify training gaps early and arrange additional clinical exposure where needed.

Access to trainee data should be role-based and limited to authorised trainees, supervisors and programme administrators. Data should be stored on secure institutional platforms, with appropriate authentication, audit trails and confidentiality safeguards in accordance with institutional policies.

13.4.3 Data Dashboards and Learning Analytics

Complementing these systems are programme-level dashboards and learning analytics. These tools pull together data from multiple sources — volume of cases performed, assessment outcomes, research progress, attendance and participation — to paint a comprehensive picture of trainee development.[9] The visualisation of trends allows programme coordinators to make informed, data-driven decisions,[10] strengthening the consistency and fairness of the training experience.

In IIUM's anaesthesia training, this concept is supported through the use of iPortfolio, a digital student portfolio developed by a faculty member within the programme. Trainees record their procedure logbooks, competency assessments and training milestones. The iPortfolio is an integrated dashboard that provides visual summaries of trainee progression at both programme and individual levels. Each lecturer or trainer also has access to iSupervise, another dashboard for academic supervisors to monitor the progress of trainees under their supervision, including procedure

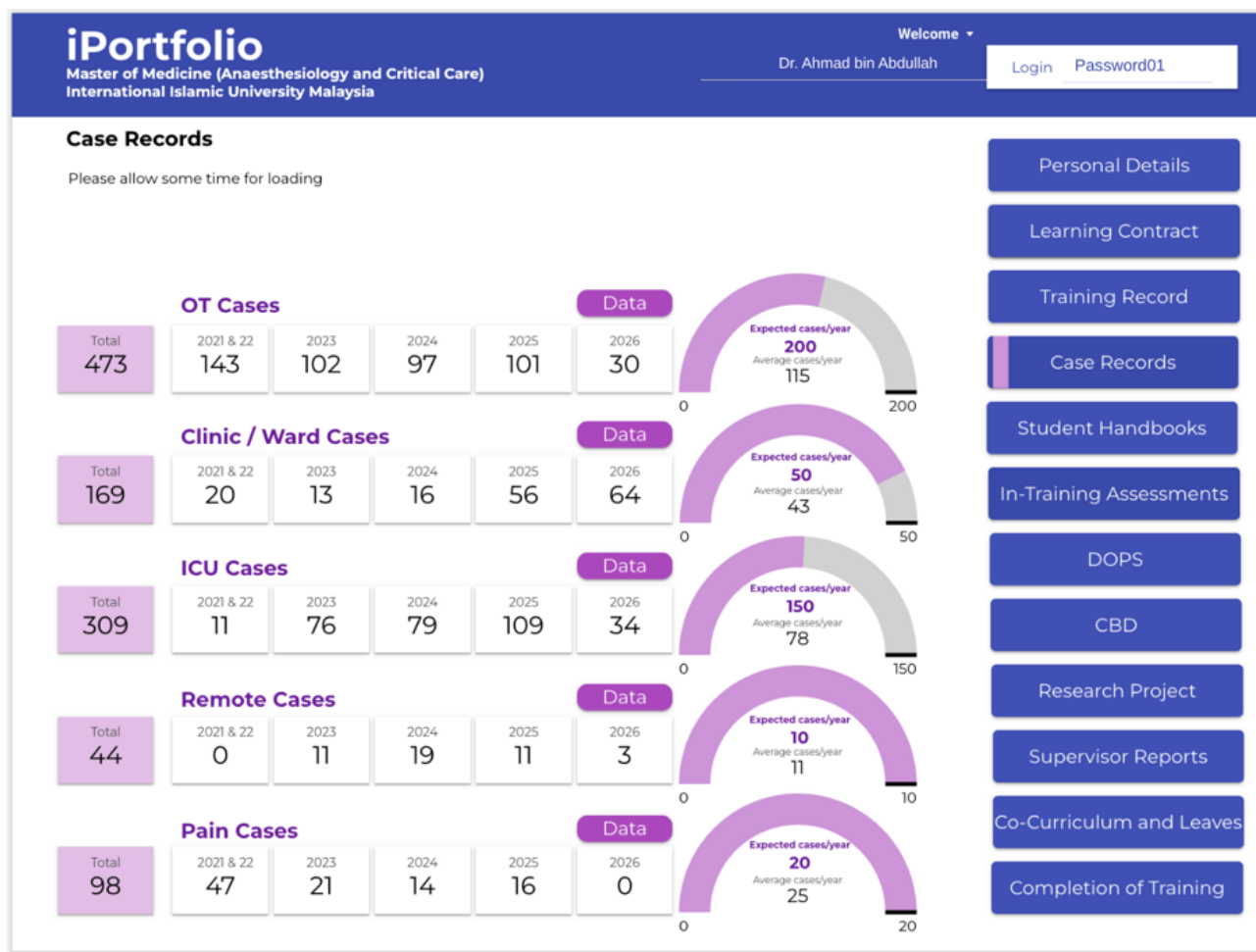


Figure 13.1: IIUM iPortfolio dashboard for monitoring trainee case volumes. The system enables early identification of trainees who have not yet achieved the required procedural exposure.

logs, completed assessments and competency status. This combination of digital portfolios and analytic dashboards strengthens programme oversight while helping supervisors provide more guidance and timely feedback to their trainees.[11]

Across different settings, programmes should select tools that align with local needs, available infrastructure and staff capacity, while ensuring that digital data support rather than replace educators' professional judgement.

13.4.4 Automated Reminders

Automation can also make programme governance much smoother by handling routine reminders and notifications in the background. In busy clinical training environments, it is easy to get caught up in tasks such as logbook updates, assessment submissions, or rotation reports, which require time from clinical schedules. Automated reminder systems can gently prompt users when something requires attention.[12] For instance, trainees may receive a notification to update their digital logbook after a certain period of inactivity, while supervisors can be alerted when an assessment form is pending review.

These reminders can be implemented using simple digital tools that many programmes already use. For example, if procedure data are collected through online forms that feed into a spreadsheet, simple automation rules can be set to monitor activity. If a trainee has not submitted a logbook entry for 1 or 2 weeks, the system can automatically send a reminder email prompting them to update their records. Similarly, when a workplace-based assessment form is submitted through a digital form, the system can notify the supervisor to review and confirm the assessment.

LMS also supports this process. Platforms such as iTa'LeEM (Moodle) at IIUM send automated notifications when assignments, quizzes, or evaluation forms remain incomplete.[13] Trainees receive reminders as deadlines approach, while lecturers can see which assessments are still pending.

Another practical approach is to link spreadsheets to email automation tools or messaging integrations. For instance, a spreadsheet tracking assessment completion can trigger an automatic message when the status column remains set to 'pending' after a specified number of days. These small digital nudges help keep training records up to date without requiring programme coordinators to chase every

update manually.[9] Over time, such automation not only improves the timeliness of documentation but also makes programme governance more efficient and manageable.

13.5 Conclusion

As anaesthesia training programmes continue to expand, strong programme governance remains essential to ensure trainee competency and patient safety. While trainers remain central to the development of future specialists, digital technologies can play an important supporting role. Simple digital tools can improve documentation, monitoring and communication within training programmes. By integrating these practical solutions, programmes can streamline governance processes and allow educators to focus more on mentoring and developing the next generation of anaesthesiologists. Programmes can begin by piloting one or two tools, evaluating their usefulness and feasibility, and expanding them gradually based on feedback.

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Future-Ready Anaesthesia: Negotiating the Intersection of Smart Technology, AI, and Clinical Decision Support

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KEY POINTS

- Artificial intelligence (AI) is increasingly integrated into perioperative and critical care medicine.
- AI should be viewed as a form of augmented intelligence that complements, rather than replaces, clinician expertise.
- Current applications span the entire perioperative continuum, including preoperative risk stratification, intraoperative haemodynamic prediction, automated drug delivery and critical care analytics.
- Despite promising results, AI systems require rigorous external validation, ongoing monitoring and careful assessment of generalizability across different patient populations.
- Challenges include algorithm bias, AI hallucinations, alert fatigue, workflow integration, cybersecurity concerns and medico-legal uncertainty.
- Most regulatory authorities continue to emphasise that AI systems should function as decision support tools, rather than autonomous decision makers.
- In Malaysia, cost remains one of the most significant challenges in the implementation of AI systems.
- Education and research represent two areas in which AI may profoundly reshape the future of anaesthesiology.
- Future-ready anaesthetists will require competencies in AI literacy, data interpretation and critical appraisal to ensure safe and effective implementation.

Keywords: Artificial Intelligence, Anaesthesia, Clinical Decision Support Systems, Machine Learning, Perioperative Medicine, Smart Technology, Future-Ready Healthcare

14.1 Introduction

The modern practice of anaesthesiology and critical care is experiencing a significant paradigm shift. As we embrace the theme of “Future-Ready Anaesthesia” for 2026, the focus has progressed beyond basic digitization of electronic health records (EHRs) and traditional monitoring. We are now entering the era of augmented intelligence. In environments characterized by large volumes of high-velocity physiological data, Artificial Intelligence (AI) and advanced Clinical Decision Support Systems (CDSS) are fundamentally transforming how we predict risk, deliver intraoperative care, and manage critical illness.

Within perioperative medicine and intensive care, AI applications now extend across the entire patient journey, from preoperative risk stratification to intraoperative drug titration and postoperative outcome prediction. These technologies constitute an essential part of a “future-ready” anaesthesia practice, enhancing clinician expertise while addressing the growing complexity of modern healthcare systems.

14.2 Understanding AI: Capabilities and Limitations

Artificial intelligence broadly encompasses computational systems capable of performing tasks that typically require human cognitive functions, including pattern recognition, prediction, and decision making. Machine learning (ML), a principal subset of AI, enables algorithms to identify patterns within large datasets and generate predictive models without predefined programming.[1] However, AI should never be viewed as a substitute for clinical judgement. Contemporary AI systems do not possess consciousness, empathy, intuition, moral reasoning, or independent decision making capabilities. Rather, they generate outputs based on patterns learned from training data. They cannot independently assume professional responsibility for patient care decisions.

AI systems are fundamentally dependent on the quality, completeness, and representativeness of the data used during development. Hence, inaccurate, incomplete, or biased datasets may result in unreliable predictions. Furthermore, generative AI systems may occasionally produce plausible but incorrect outputs, a phenomenon commonly referred to as “AI hallucination”. In healthcare, such errors have potential significant consequences and underscore the importance of maintaining human oversight in all AI-assisted clinical decision making.[2]

In anaesthesia, AI applications are commonly integrated into clinical decision support systems that analyse patient data in real time and provide recommendations, alerts, or predictions to support clinical judgement.

14.3 The Preoperative Paradigm: Precision Risk Stratification

Historically, preoperative assessment has relied on generalized scoring systems such as the ASA physical status classification. Although these tools are clinically foundational, they lack the precision of individualized care. Currently, machine learning (ML) algorithms leverage comprehensive electronic health records (EHRs), laboratory data, and physiological parameters to generate highly personalised risk stratifications.[3, 5]

Recent AI-based platforms, such as the MySurgeryRisk calculator, have demonstrated superior accuracy in predicting postoperative complications including acute kidney injury, delirium, and mortality, compared to traditional risk calculators. Despite being validated in a large multicentre cohort, it is unlikely that MySurgeryRisk will perform to the exact same degree in Malaysia without local recalibration, as the populations in the US or Europe (where the AI was largely developed) have different baseline risks for cardiorespiratory complications compared to Malaysia’s multi-ethnic demographic.[4] Deep learning and computer vision are revolutionizing airway assessment. Image-based AI that analyses ultrasound scans and facial phenotypes can now predict difficult intubation with remarkable accuracy, allowing clinicians to formulate proactive airway management strategies and facilitate resource allocation.[3, 6]

While thousands of AI and machine learning models boast excellent technical metrics, many fail to translate into tangible bedside benefits or are quickly abandoned by clinicians. Herein lies the problem of the AI chasm in medicine. The experience of the Epic Sepsis Model shows that AI systems are not infallible. Although designed to facilitate early sepsis detection, subsequent evaluations demonstrated lower than expected sensitivity and a substantial number of false positive alerts in real world clinical environments. Such findings highlight the importance of independent validation, continuous monitoring, and cautious interpretation of AI generated recommendations.[7]

14.4 Intraoperative Smart Technologies and Autonomous Care

In the operating room, AI applications are advancing from passive monitoring toward active predictive analytics and closed-loop systems.

- **Predictive Haemodynamics:** Traditional monitoring is reactive, with clinicians intervening only after a parameter breaches a threshold. Advanced ML algorithms, utilizing arterial waveform analysis (such as the Hypotension

Prediction Index), can now predict intraoperative hypotensive events up to 15 minutes in advance. This provides the anaesthetist with a crucial window for preventative intervention, thereby minimizing end organ hypoperfusion.[3, 6] However, the clinical impact of predictive monitoring remains an area of ongoing investigation. While several studies have demonstrated reductions in hypotension burden, evidence regarding improvements in major patient centred outcomes remains less definitive. Furthermore, concerns have been raised regarding alarm fatigue, false positive alerts and the need for clinicians to interpret algorithm generated predictions within broader clinical context.[8]

- **Closed-Loop and Autonomous Systems:** The holy grail of “smart” anaesthesia is automated drug delivery. Closed-loop target-controlled infusion (TCI) systems that utilize continuous electroencephalogram (EEG) feedback are being refined to automatically titrate propofol and remifentanyl. By continuously interpreting the depth of anaesthesia through complex neural network analysis, these systems maintain hemodynamic stability and reduce the risk of accidental awareness or burst suppression, thereby optimizing both safety and medication use.[3] Despite these promising developments, fully autonomous anaesthesia remains unlikely in the foreseeable future. Anaesthetic management involves numerous contextual factors, including surgical complexity, patient preferences, ethical considerations and unexpected intraoperative events that cannot currently be managed reliably by automated systems alone. Contemporary expert opinion increasingly favours a model of supervised autonomy, in which clinicians remain actively involved in oversight and decision making.[9]

14.5 Critical Care: Predicting the Unpredictable

The intensive care unit (ICU) generates terabytes of data each day, representing a volume that is impossible for any human to synthesize in real time. In this context, AI excels as a continuous background processor.[6]

This is notably evident in sepsis management. Sepsis remains a leading cause of ICU mortality, primarily due to delayed recognition. State-of-the-art predictive models utilizing gradient boosting algorithms (such as XGBoost) can analyse subtle, multi-granular trends in vital signs and laboratory results to predict the onset of sepsis and septic shock hours before clinical symptoms appear. Additionally, unsupervised ML clustering is facilitating the classification of sepsis into distinct clinical phenotypes, guiding tailored resuscitation strategies for fluid administration and

vasopressor selection.[6, 10, 11, 12]

14.6 The Human-AI Synergy in Decision Support

Modern Clinical Decision Support Systems (CDSS) are designed to reduce, rather than increase, cognitive load. A notable limitation of early CDSS was “alert fatigue”, resulting from an overwhelming number of threshold-based alarms. Future-ready CDSS employ context-aware AI to filter irrelevant information, providing actionable and highly specific alerts. Whether recommending optimal sedation weaning protocols or cross-referencing patient comorbidities for precise drug dosing, these systems integrate seamlessly into clinical workflows.[13]

Anaesthetists frequently manage multiple data streams simultaneously. AI-assisted monitoring can reduce information overload and support more efficient decision making. In addition to that, clinical decision support tools can prompt clinicians to adhere to evidence based protocols, thereby improving consistency of care.

14.7 Implementation and Workforce Development

The successful integration of AI into routine practice depends not only on technology performance but also on clinical acceptance and workflow compatibility. AI tools often fail to blend seamlessly with existing, often old, hospital IT infrastructure. These may contribute to alert fatigue, increase workload, and disrupt established clinical processes. Implementation in routine practice remains limited by usability barriers, workflow misalignment, trust concerns, and financial and ethical constraints.[14]

Future-ready anaesthetists will therefore require competencies extending beyond traditional clinical skills, including data literacy, critical appraisal of AI outputs, and an understanding of algorithmic limitations. If junior anaesthetists become overly reliant on AI, there is a distinct risk that foundational clinical skills and independent troubleshooting capabilities may degrade. Training programmes must therefore evolve to teach not only how to use these systems, but how to safely override them. Positioning clinicians to be able to support AI integration into clinical care will require focused educational initiatives to provide clinicians with sufficient understanding of AI to propose and evaluate clinical AI applications to solve clinical needs. Collaborative initiatives by major academic institutions like UNIMAS, which include hosting the “AI Tools for Teaching, Research, and Productivity” workshop with Google for Education, have received widespread acclaim from clinicians alike as an excellent entry point into the world of AI.[14]

14.8 Challenges, Ethics, and the “Black Box”

Despite considerable potential, the transition to AI-integrated care presents significant challenges. Clinicians must approach these technologies with both enthusiasm and critical evaluation.

A primary barrier to clinical trust is the “black box” phenomenon, in which an algorithm provides a highly accurate prediction without explaining its reasoning. In critical care, where decisions are often life or death, interpretability is essential. As a result, the field is rapidly shifting toward XAI (Explainable AI), utilizing frameworks such as SHAP (Shapley Additive Explanations) to deliver transparent, biomarker-driven rationales for AI predictions.[3, 12]

We must navigate ethical considerations regarding algorithmic bias, often resulting from non-representative training data, and automation bias, in which a clinician may inappropriately defer to a machine’s judgment over their own clinical expertise.[6] Historically, clinical decision making has been the responsibility of healthcare professionals, with legal accountability resting primarily upon individual practitioners. The introduction of AI complicates this framework because recommendations may be generated by algorithms developed by third party vendors using proprietary methodologies that are not fully transparent to end users. Consequently, determining responsibility when adverse outcomes occur may become increasingly challenging. Another equally important question concerns situations in which clinicians choose not to follow AI recommendations and an adverse outcome subsequently occurs. As AI systems become widely adopted and evidence supporting their use accumulates, future medicolegal frameworks may need to address whether failure to utilise available decision support tools could itself constitute a deviation from accepted standards of care.

At present, most regulatory authorities continue to emphasise that AI systems should function as decision support tools rather than autonomous decision makers. Professional accountability therefore remains with the treating clinician, despite issues relating to the failure of AI software itself. The clinician must critically evaluate algorithm generated recommendations within the broader clinical context and exercise independent judgement when determining appropriate management.[15]

Especially in Malaysia, cost remains one of the most significant challenges. Implementation of AI systems requires not only substantial investment in digital infrastructure, data storage, and cybersecurity, but also a concerted effort to address the shortage of specialised technical expertise. Furthermore, ongoing maintenance and regular training for clinical staff add to the financial burden, potentially widening the gap in healthcare quality between higher and lower resourced institutions. This concept aligns closely with the

principles of value-based care. Something may be perfect, but if it costs hundreds or thousands more, we probably are not in a financial position to implement or to put in practice on a large scale as it does not bring value. These contextual factors highlight the need for tailored policy frameworks and strategic partnerships to ensure equitable and sustainable integration of AI across the Malaysian healthcare system. The question remains, do we have enough expertise in our country to produce similar technology, or will we have to spend millions to bring it in from overseas? Relying exclusively on expensive, imported platforms (which incur substantial ongoing maintenance and licensing costs) is financially unsustainable and risks widening the technological divide between well resourced urban centres and district hospitals.

14.9 AI in Education and Research

Although discussions surrounding AI frequently focus on clinical applications, its influence extends far beyond direct patient care. Education and research represent two areas in which AI may profoundly reshape the future of anaesthesiology.

Medical education has traditionally relied upon lectures, textbooks, bedside teaching and simulation based training. AI technologies now offer opportunities to personalise learning experiences and support competency based education. In anaesthesia, where the development of procedural expertise and situational awareness is critical, AI enhanced simulation may become an increasingly valuable educational tool. However, educators must also remain mindful of its potential limitations. Excessive reliance on AI generated content may risk reducing opportunities for independent critical thinking. Hence, AI should complement rather than replace traditional educational approaches.[16]

Research is another domain undergoing significant transformation through AI. In perioperative medicine, AI has been applied to outcomes based research, biomarker discovery, precision medicine and predictive modelling. Beyond healthcare analytics, AI is also accelerating pharmaceutical development. Drug discovery has traditionally been a lengthy and expensive process involving extensive laboratory experimentation. AI assisted approaches can rapidly screen large numbers of molecular candidates, identify promising therapeutic targets and optimise drug development pipelines.[17]

14.10 Conclusion

The future of anaesthesia is not one of machine replacement, but of a hybrid decision-making model. Rather than replacing clinicians, the future of AI in anaesthesia is increasingly conceptualised as

augmented intelligence, in which human expertise and machine learning capabilities complement each other. By delegating data synthesis and pattern recognition to smart technology, a future-ready anaesthetist is freed to focus on aspects that machines cannot replicate: clinical intuition, nuanced ethical judgment, and compassionate patient care. Those who can effectively integrate technological innovation with patient centred care will be best positioned to lead the next generation of perioperative medicine.

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Part IV

Sustainability in Anaesthesia and Intensive Care

Eco-Conscious Anaesthesia: Healing Patients, Healing the Planet

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KEY POINTS

- **Resource-Intensive Setting:** The operating theatre contributes up to 70% of hospital waste, making it a critical target for sustainability interventions.
- **Anaesthetic Gas Impact:** Halogenated agents and nitrous oxide carry significant global warming potential, with desflurane being the most environmentally harmful.
- **Drug and Consumable Wastage:** Routine preparation of excess medications and inappropriate equipment sizing contribute substantially to avoidable waste.
- **Low-Flow Anaesthesia:** Reducing fresh gas flow during maintenance is a key strategy for minimising volatile agent emissions and environmental burden.
- **Behavioural and Administrative Reform:** Embedding green practices into operating theatre culture through education, digital documentation, and power-down protocols is essential.
- **National Commitment:** Malaysia's Carbon Neutral Healthcare Facilities Blueprint targets complete carbon neutrality by 2045, with anaesthesia departments positioned to lead institutional sustainability.

15.1 Towards Green and Sustainable Anaesthesia

The operating theatre is among the most resource-intensive areas in any hospital, contributing up to 70% of hospital waste.[1] For decades, our focus has rightly been on the patient before us. Yet, to safeguard the wellbeing of future generations, we must broaden our vision and embrace the principles of Green and Sustainable Anaesthesia.

“Green Anaesthesia” is the integration of ecologically sustainable and environmentally conscious practices into perioperative care. By aligning environmental health with economic efficiency and social responsibility, sustainability ensures the long-term viability of healthcare systems. Importantly, while we strive to reduce our ecological footprint, the foremost responsibility of every anaesthetist remains unchanged: the uncompromising commitment to patient safety.

15.2 Environmental Responsibility in Anaesthesia Practice

The environmental impact of medical gases, particularly their contribution to the greenhouse effect, has become a pressing issue. While intravenous anaesthesia is often considered as an alternative, this approach carries its own environmental and financial challenges. With short procedures and processed EEG usage, TIVA may cost more than its carbon footprint savings.[2, 3] “From an economic view, sustainability requires not just substitution, but behavioural change to reduce” wastage of resources.[4] Careful and thoughtful use of medical supplies and gases—applied consistently across all aspects of practice—can significantly reduce environmental burden while maintaining the highest standards of patient care.

15.3 Anaesthetic Consumables and Drug Wastage

Significant anaesthetic wastage often begins even before the patient arrives in the operating room. This includes discarded plastic packaging from instruments, equipment, and tubing supplies, as well as unused syringes, papers, and IV connectors.[5, 6] Intraoperatively, wastage is further driven by inefficient administration of inhalational agents through high gas flows.

Intravenous drug wastage is equally prevalent. Medications such as rocuronium and propofol are frequently prepared but discarded unused, sometimes accounting for up to one-third of total drug wastage.[7] Other commonly discarded agents include thiopental, opioids, phenylephrine, ephedrine, atropine, and

adrenaline. Consumables such as ECG electrodes and circuit components add further to the waste stream, often worsened by inappropriate segregation of waste. In addition, inappropriate size selection of laryngeal mask airway (LMA), endotracheal tube (ETT) and intravenous cannula are also source of wastage. Since 2022, the Royal Colleges of Surgeons in Edinburgh, England, and Glasgow have published the Intercollegiate Green Theatre Checklist—a 16-item framework designed to embed sustainability across the surgical journey, from anaesthesia and preparation to equipment use and postoperative care, with a strong focus on reducing resource waste.[8] Despite these realities, many anaesthesia professionals remain unaware of the true costs of these drugs and the total volume of waste generated in their daily practice.

15.4 Impacts of Anaesthesia Wastage

The environmental impact of halogenated anaesthetic agents is measured through their Global Warming Potential over a 100-year horizon (GWP₁₀₀). Among these agents, desflurane (GWP₁₀₀ = 2450) has the highest impact, followed by isoflurane (GWP₁₀₀ = 510) and sevoflurane (GWP₁₀₀ = 130).[9] Nitrous oxide (GWP₁₀₀ = 198, atmospheric lifetime 114 years) remains a major global concern, ranked as the third most significant greenhouse gas worldwide after carbon dioxide and methane. This ranking reflects its overall atmospheric contribution, not just healthcare-related emissions.[10]

Beyond gases, the disposal of unused drugs and patient excretions contributes to complex waste streams, introducing plastics, paper, and glass into the environment. When untreated pharmacological waste enters ecosystems, it poses biological hazards, disrupts local environments, and contributes to long-term ecological degradation.

15.5 Strategies for Reducing Anaesthetic Wastage and Environmental Impact[11]

1. Optimization of Gas Delivery

- Adopt low-flow anaesthesia by reducing fresh gas flow (FGF) during maintenance and turning off FGF during intubation or disconnection.[12] However, challenges such as circuit leaks, staff training, and organisational culture must be addressed.[13]
- Select lower-emission agents and maintain appropriate MAC (Minimum Alveolar Concentration).
- Ensure technical vigilance, including proper cuff inflation and routine machine maintenance, to prevent leaks.

- Implement Waste Anaesthetic Gas (WAG) capture systems, such as Deltasorb canisters, to trap halogenated agents before they enter the environment.[14, 15] However, the efficiency of these systems is relatively low, and the resulting increase in cost poses a substantial challenge for low- and middle-income countries. It should only be employed after practice efficiencies have been maximized.[16, 17]

2. Pharmaceutical and Physical Waste Mitigation

- Limit the number of drugs routinely prepared to what is clinically anticipated.
- Use prefilled syringes and smaller vial sizes to reduce discard volumes. Prefilled syringes can reduce the professional time required for preparation and labelling, lower the risk of medication errors, and decrease potential medicolegal costs, while also limiting wastage despite their higher purchase price. However, practical considerations such as the risk of microbial contamination, the costs of sharps disposal, and the storage requirements for prefilled syringes are often overlooked.[18, 19]
- Segregate and dispose of pharmaceutical waste properly to prevent hazardous runoff.
- Consider transitioning toward reusable items such as LMAs, laryngoscopes, surgical gowns, and drapes, which may provide long-term environmental benefits despite varying cost ratios across countries and depending on patient volume.[20, 21, 22, 23, 24] There is no evidence to suggest that reusable devices carry an increased risk of infection. However, given that the sterilisation process is highly electricity-intensive, reliance on fossil fuel-based electricity generation may offset the anticipated environmental benefits.[16]

3. Administrative and Behavioural Reform

- Adopt digital health documentation systems to mitigate the environmental burden of paper-based recording.
- Establish rigorous power-down protocols for clinical apparatus during periods of inactivity to optimize energy efficiency.
- Promote education and advocacy to embed “green practices” into the operating theatre culture, ensuring sustainability becomes a standard of clinical excellence rather than an afterthought.

15.6 Conclusion: A Strategic Roadmap for Sustainable Practice in Malaysia

As anaesthesia professionals, we stand at the unique intersection of acute patient care and environmental stewardship. The healthcare sector is fundamentally designed to save lives, yet globally it accounts for 5% of greenhouse gas emissions—a paradox we can no longer ignore.

Simply reacting to these climate-induced health burdens is insufficient; we must address our own carbon footprint. In alignment with the Ministry of Health’s (MOH) national mandates—including the target for 100% Green Building Certification across all 148 public hospitals and the ambitious Carbon Neutral Healthcare Facilities Blueprint aiming for complete carbon neutrality by 2045—the anaesthesia department must transform from a primary waste generator into a leader of institutional sustainability.

To transition from abstract advocacy into an audit-ready clinical reality, our society is committed to leading this transformation—championing awareness, education, and innovation in Green Anaesthesia across Malaysia and beyond. By adopting the structured architecture of the CoA-MSA Consensus Statement on Green Anaesthesia: A Starter Toolkit, we can systematically deploy high-impact interventions across our practice. Together, we can ensure that excellence in anaesthesia goes hand in hand with responsibility to our planet, safeguarding the health of our patients today while protecting the wellbeing of future generations.

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Sustainable Pain Medicine in Anaesthesia Practice

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Abstract

Sustainable pain medicine is essential to support recovery, early mobilisation, respiratory function, and patient satisfaction. However, modern anaesthesia practice must balance adequate analgesia with responsible opioid use, avoidance of unnecessary polypharmacy, and prudent use of healthcare resources.

Effective perioperative pain management offers a framework for delivering individualized, evidence-based analgesia that prioritizes patient safety, functional recovery, and long-term healthcare value. This article highlights rational multimodal analgesia, opioid stewardship, prevention of persistent postsurgical pain, and recovery-focused outcomes rather than pain score reduction alone. Anaesthesiologists are well placed to lead sustainable pain practice through enhanced recovery after surgery (ERAS) pathways, regional anaesthesia, audit, education, and protocol development.

16.1 Introduction

Effective pain management is a fundamental component of perioperative care and remains one of the core responsibilities of anaesthesiologists. Adequate analgesia not only improves patient comfort but also facilitates early mobilization, enhances respiratory function, and supports faster recovery following surgery. In contrast, poorly controlled pain can delay rehabilitation, prolong hospital stay, increase healthcare costs, and contribute to the development of persistent postsurgical pain.[1, 2]

For many years, opioids were regarded as the cornerstone of postoperative pain management. When the concept of pain as the “fifth vital sign” was introduced, it encouraged more aggressive treatment of pain, particularly in the United States.[8] This movement led to a substantial increase in opioid prescribing in both inpatient and outpatient settings. Over time, unintended consequences of liberal opioid prescribing became apparent. While the United States experienced a major opioid crisis characterized by widespread opioid misuse, addiction, and opioid-related mortality, opioid abuse is not the dominant trend in Malaysia; instead, drugs like methamphetamine, heroin, and ecstasy are more commonly abused.[3, 8]

In response, healthcare systems introduced opioid stewardship programs, stricter prescribing regulations, and greater emphasis on responsible opioid use.[8, 10] While these measures were necessary to reduce opioid-related harm, they also created a new challenge for clinicians. Increasingly, both healthcare providers and patients have become cautious about opioid use, sometimes leading to inadequate pain control.

Modern anaesthesia practice therefore faces the challenge of balancing effective analgesia with responsible opioid use. Within this context, the concept of sustainable pain medicine has emerged, referring to the delivery of effective analgesia while minimizing adverse effects, avoiding unnecessary interventions, and ensuring responsible utilization of healthcare resources. This approach aligns with the broader movement toward value-based healthcare, where clinical outcomes, patient safety, and long-term sustainability of healthcare systems are equally emphasized.[5, 6]

16.2 Individualized and Evidence-Based Analgesia

Pain perception varies considerably between individuals and is influenced by a combination of biological, psychological, and social factors. Consequently, analgesic strategies should be individualized based on patient characteristics, surgical factors, and anticipated postoperative pain intensity.[2, 6]

Multimodal analgesia is one of the key components of perioperative pain management. This strategy

combines analgesic medications and techniques that act through different mechanisms to achieve superior pain control while reducing reliance on opioid.[2, 7, 9] Multimodal analgesia includes paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs), regional anaesthesia techniques, and selected adjuvant medications such as ketamine or dexamethasone.[2, 7]

Clinical practice guidelines strongly support the use of multimodal analgesia because it improves analgesic efficacy while reducing opioid consumption.[2, 7] However, sustainability emphasizes rational multimodal therapy rather than simply adding multiple medications indiscriminately. Excessive polypharmacy may increase adverse effects such as sedation, nausea, renal impairment, or postoperative delirium without providing additional analgesic benefit.[2, 7]

The concept of “right-sized analgesia” is therefore central to sustainable pain medicine. Rather than aiming for complete elimination of pain, which may not be achievable in many surgical situations, the goal is to provide sufficient analgesia to enable patients to breathe comfortably, mobilize early, and participate in rehabilitation.[5, 6]

16.3 Opioid Stewardship

Opioids remain an important component of perioperative analgesia, particularly for moderate to severe postoperative pain.[2] Nevertheless, growing evidence suggests that perioperative opioid exposure may contribute to persistent opioid use following surgery.[3, 10] Studies have shown that a proportion of opioid-naïve patients exposed to opioids during the perioperative period continue opioid use months after surgery.[3]

Opioid stewardship therefore represents a key pillar of modern perioperative pain management. This concept involves ensuring that opioids are prescribed appropriately, safely, and only when clinically indicated.[8, 10] Strategies include minimizing intraoperative opioid exposure when feasible, implementing opioid-sparing techniques such as regional anaesthesia, and limiting discharge prescriptions to the smallest effective quantity.[7, 10]

Patient education is equally important and should not be overlooked. Patients should receive clear counselling regarding expected postoperative pain, safe opioid use, and appropriate tapering strategies after discharge. Such communication helps reduce the risk of prolonged opioid use while maintaining adequate pain control.[2, 10]

Opioid stewardship does not imply avoidance of opioids. Undertreatment of pain can impair recovery, increase physiological stress responses, and negatively affect patient satisfaction.[2, 6] Balanced opioid use, where opioids are integrated appropriately within a comprehensive multimodal analgesic plan, should be

adopted.[7, 8]

16.4 Prevention of Persistent Postsurgical Pain

Persistent postsurgical pain is an increasingly recognized complication of surgery, affecting approximately 10–20% of surgical patients.[4] This condition can significantly impair quality of life and lead to long-term healthcare utilization. The development of persistent postsurgical pain involves complex mechanisms including nerve injury, central sensitization, and psychological factors.[4] Severe acute postoperative pain has consistently been identified as one of the strongest predictors of chronic pain development.[4]

Early identification of patients at higher risk is therefore essential. Individuals with pre-existing chronic pain conditions, psychological vulnerability, or opioid tolerance may require more comprehensive perioperative pain management strategies.[2, 4] Effective acute pain control plays an important role in preventing central sensitization. Regional anaesthesia techniques, multimodal analgesia, and early postoperative rehabilitation may all contribute to reducing the risk of persistent postsurgical pain.[2, 4, 6]

Emerging evidence also suggests that perioperative anaesthetic and analgesic interventions may influence immune function and inflammatory responses, which could potentially affect long-term outcomes in certain patient populations.[11, 12, 13]

16.5 Common Analgesic Drugs and Their Role in Sustainable Pain Medicine

A variety of pharmacological agents are used in perioperative pain management, each with different benefits and limitations. The choice of analgesic should not be based solely on efficacy, but also on safety, opioid-sparing potential, effect on recovery, and appropriateness for the individual patient.[2, 7, 9]

16.6 Challenges in Implementation

Despite increasing awareness of sustainable healthcare practices, translating these principles into routine clinical care remains challenging. One important issue is the growing complexity of the surgical population. Many patients presenting for surgery today are older, more frail, and are associated with multiple comorbidities. A significant proportion also have chronic pain, pre-existing opioid exposure, anxiety, sleep disturbance, or other factors that complicate

perioperative pain management. In such patients, analgesic decisions are rarely straightforward. A regimen that works well for one patient may be ineffective or poorly tolerated in another. As a result, one cannot rely entirely on standard protocols, but rather individualized judgement, flexibility, and close follow-up.[2, 4]

Operational limitations also play a major role. While multimodal analgesia and regional anaesthesia are widely advocated, successful implementation depends on trained personnel, appropriate equipment, adequate time, and good communication between teams. In busy institutions, theatre schedules are tight, staffing may be limited, and access to ultrasound machines or block rooms may not always be ideal. Even when a regional technique is clinically appropriate, practical constraints may prevent it from being performed consistently. Similarly, prescribing at discharge requires coordination between anaesthesiologists, surgeons, ward teams, pharmacists, and nursing staff. Without a shared approach, practice may become variable, and patients may either receive too little analgesia or excessive quantities of medication.[2, 7]

Another challenge lies in culture and expectations. Pain management is still frequently judged by numerical pain scores, even though these do not always reflect overall recovery or functional improvement.[5, 6] Both clinicians and patients may sometimes equate excellent pain care with complete pain relief, which is not always realistic after major surgery. This can unintentionally encourage escalation of analgesics without sufficient attention to function, adverse effects, or longer-term consequences. At the same time, concerns arising from the opioid crisis may push some clinicians too far in the opposite direction, resulting in fear of prescribing opioids even when they are clearly indicated. A shift in mindset, from simply chasing lower pain scores to aiming for meaningful recovery, safe mobilization, and balanced prescribing might be more ideal.[8]

Environmental and system-level considerations add another layer of complexity. Operating theatres are resource-intensive environments, and pain-related care is not exempt from this. Drug wastage, unnecessary opening of disposables, over-preparation of infusion systems, and inconsistent use of high-cost techniques may all contribute to inefficiency. Although patient safety must remain the primary priority, a greater awareness of how everyday clinical choices affect not only the individual patient, but also the wider healthcare system is important. Changing these habits is often difficult because they are embedded in routine workflow. For this reason, implementation of this practice is not just a clinical issue, but also an organizational and cultural one.

Table 16.1: Common drugs used in pain management

Drug / Group	Main Role in Perioperative Pain Management	Advantages in Sustainable Pain Medicine	Limitations / Considerations
Paracetamol	Baseline non-opioid analgesic for mild to moderate pain	Widely available, inexpensive, opioid-sparing	Caution in severe liver disease
NSAIDs / COX-2 inhibitors	Anti-inflammatory analgesia	Reduce opioid requirement, improve recovery	Renal impairment, bleeding risk
Opioids	Moderate–severe pain control	Highly effective analgesia	Risk of dependence and adverse effects
Ketamine	Adjunct analgesic	Opioid-sparing, reduces central sensitisation	Psychomimetic effects
Gabapentinoids	Neuropathic pain component	Opioid-sparing in selected cases	Sedation and dizziness
Dexamethasone	Anti-inflammatory and antiemetic adjunct	Simple single-dose opioid-sparing effect	Hyperglycaemia risk
Regional local anaesthetics	Nerve blocks and neuraxial techniques	Targeted analgesia, improved recovery	Requires expertise
Alpha-2 agonists	Adjunct analgesia	Sedation with analgesic-sparing effects	Hypotension, bradycardia
Tramadol	Intermediate analgesic	Useful where strong opioids unnecessary	Nausea, variable response

16.7 Opportunities for Anaesthesia Leadership

These challenges also create significant opportunities for anaesthesiologists to take leadership in shaping better perioperative pain practice, who are involved across the whole surgical pathway, from preoperative assessment and intraoperative management to acute pain review and postoperative recovery. They are well placed to influence how analgesia is planned and delivered. This position allows anaesthesiologists not only to prescribe medication, but also to shape broader pain strategies that prioritize function, safety, and recovery. In many ways, this is an area in which anaesthesiology can demonstrate leadership beyond the operating theatre.

One of the clearest opportunities lies in the development and refinement of Enhanced Recovery After Surgery (ERAS) pathways. ERAS programmes have already shown how coordinated perioperative care can improve outcomes by combining multimodal analgesia, reduced opioid exposure, early feeding, and early mobilization.[5, 9] Within these pathways, anaesthesiologists play a major role in selecting analgesic techniques that are effective yet practical, and in ensuring that pain management supports rather than delays recovery. Sustainable pain medicine fits naturally within this philosophy, because it encourages clinicians to focus on interventions that provide real

benefit to patients while avoiding unnecessary harm, cost, and variation in practice.

Regional anaesthesia also represents an important area of leadership. When applied appropriately, peripheral nerve blocks and neuraxial techniques can reduce systemic opioid requirements, improve respiratory function, and facilitate earlier mobilization.[2, 7] However, the true value of regional anaesthesia lies not only in performing more blocks, but in performing the right block for the right patient in the right context. Anaesthesiologists are uniquely positioned to decide when a regional technique is likely to add meaningful value and when a simpler approach may be more appropriate. A balanced decision making is prudent, where the goal is high-value analgesia rather than maximal intervention.

Anaesthesiologists often meet patients at a point of understandable anxiety, when uncertainty about pain and recovery is high, in which patient education and managing expectation setting is crucial. Clear preoperative counselling can make a substantial difference. When patients understand that the goal is tolerable pain rather than complete absence of discomfort, and that movement and rehabilitation remain important, they are often better prepared for recovery. This reduces fear, improves satisfaction, and may decrease over-reliance on opioids.[2, 10] In this way, communication becomes an important analgesic tool in itself.

Anaesthesia departments can drive this practice through audit, education, and quality improvement. Reviewing opioid prescribing patterns, discharge prescriptions, block utilization, pain outcomes, and adverse effects can reveal important gaps between intended and actual practice. These data can then guide targeted interventions, such as standardized discharge prescriptions, education on opioid tapering, or improved selection of regional techniques. Teaching trainees and junior staff to think in terms of value, recovery, and stewardship will also be essential for long-term change. This practice is therefore not simply a set of drug choices, but an evolving professional responsibility. By leading this shift, anaesthesiologists can help ensure that perioperative pain management remains effective, safe, and relevant to the future needs of patients and healthcare systems.[2, 5]

16.8 Conclusion

Sustainable pain medicine represents an important evolution in contemporary anaesthesia practice. It reflects a shift away from viewing pain management purely as the reduction of pain scores, and toward a broader understanding of perioperative recovery, patient safety, and long-term wellbeing. The lessons learned from the opioid crisis have made it clear that effective analgesia must always be balanced against potential harm. At the same time, fear of opioids should not lead to undertreatment of acute postoperative pain. The aim is not opioid elimination, but more thoughtful, selective, and responsible use within a wider multimodal strategy.[3, 8, 10]

In practical terms, anaesthesiologists have to consider not only what works, but what works safely, appropriately, and consistently for the individual patient. This includes the use of individualized multimodal analgesia, careful opioid stewardship, prevention of persistent postsurgical pain, and attention to recovery-focused outcomes such as mobilisation, respiratory function, and return to normal activity.[2, 4, 5, 7] It also encourages a more considered approach to healthcare resources, recognising that good pain management should be clinically effective without becoming unnecessarily burdensome to the wider system.

Differences in patient complexity, institutional resources, staff expertise, and local culture mean that practice will continue to vary. However, these same challenges create opportunities for anaesthesiologists to lead change through education, protocol development, regional anaesthesia services, ERAS pathways, and continuous audit of prescribing and recovery outcomes.[2, 5, 9]

As perioperative care continues to evolve, anaesthesiologists will remain central to shaping how pain is understood and managed. By combining sound clinical judgement with evidence-based analgesic strategies and a broader awareness of long-term

consequences, anaesthesiologists can help ensure that perioperative pain management remains effective, safe, and high value for both patients and healthcare systems alike.

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