https://doi.org/10.60115/11055/1387

Goal-directed bleeding management: Understanding and implementing viscoelastic haemostatic assays across patient blood management

Dr Sukhi Hegde MBBS (Hons) M. Med (Critical Care Medicine)

Fellow in Cardiothoracic Anaesthesia, Liverpool Hospital, Sydney, Australia

Dr Sukhi Hegde is a former Prince of Wales trainee currently completing a cardiothoracic anaesthesia fellowship at Liverpool Hospital in Sydney. She is a co-chair of the ANZCA trainee committee. Sukhi's interests include patient blood management, medical education, sustainability and mentorship.

Dr Bronwyn Pearse PhD MNP MClinPract (Acute Cardiac Nursing)

Nurse Practitioner, Patient Blood Management, Prince Charles Hospital, Brisbane, Australia

Dr Bronwyn Pearse works in blood management at the Prince Charles Hospital and is a patient blood management (PBM) advisory committee member for the National Blood Authority (NBA), the co-deputy chair of the Metro North Hospital and Health Service PBM committee, and a scientific associate for the International Foundation for Patient Blood Management.

Kathryn Santifort RN BSN GradDipN (Anaesthetics and Recovery)

Nursing Unit Manager/Floor Coordinator, Operating Theatres, Prince of Wales Private Hospital, Sydney, Australia

Kathryn Santifort is the representative for the Randwick campus transfusion committee for the Prince of Wales Private Hospital and has a special interest in anaesthetic emergencies and patient blood management. She has previously co-authored with Dr Downs on VHA in *Australasian Anaesthesia* in 2017.

Dr Lisa Clarke MBBS FRACP FRCPA MEpi (Clin)

Clinical and Laboratory Haematologist and Transfusion Medicine Specialist, Sydney, Australia

Dr Lisa Clarke facilitates the Australian Red Cross Lifeblood clinical transfusion program and has been published in the area of patient blood management.

Dr Catherine Downs MBBS (Hons 1) FANZCA MClin Ultrasound

Specialist Cardiothoracic and Obstetric Anaesthesiologist, Prince of Wales Public Hospital, Sydney, Australia

Conjoint Senior Lecturer, School of Clinical Medicine, University of New South Wales, Sydney, Australia

Dr Catherine Downs introduced viscoelastic testing to Randwick Hospital Campus in 2015 and has been the chair of the ROTEM working party and involved in medical education of goal-directed bleeding management for more than a decade. She has lectured on the Lifeblood clinical transfusion course, and at many local and international meetings.

Edited by Dr Kate Drummond

INTRODUCTION

Recent decades have seen increasing awareness of the risks of transfusion, along with recognition of the need for a sustainable approach to managing finite blood products.[1,2] These concepts, combined with an increasing body of work addressing strategies that optimise and conserve patients' own blood, have led to the emergence of the patient blood management (PBM) paradigm.[3] The concept of PBM is to support the health of an individual's blood and the physiological integration and impact on all other body systems which, as a corollary, often reduces the risk of requiring allogeneic blood transfusion.[4,5] Specifically, this paradigm seeks to decrease avoidable blood loss and support prompt cessation of bleeding with the aim to reduce transfusion-related morbidity and mortality.[6,7]

The World Health Organization has mandated the evidence-based, ethical, and economic argument to implement PBM globally; a sentiment that has been echoed by our Australian National Blood Authority

(NBA).[8,9] The mandate to improve blood health and apply PBM strategies will become more important over time as the balance of demand and supply for blood products shifts.[8,9] Adding to the change in the supply/demand balance is a population that is living longer, where more complex surgeries are being offered to older patients with increased comorbidities and an increased likelihood of requiring perioperative blood transfusion.[10-14] Furthermore, emerging evidence about the carbon footprint of transfusion-related products supports the need to improve the sustainability of healthcare practices.[15] Perioperative clinicians are well-placed to have an impact on blood product demand through goal-directed bleeding management (GDBM).

GDBM is an important and effective strategy to address PBM.[6] Appropriate management of perioperative blood loss, bleeding and acquired coagulopathy improves patient outcomes.[6,16] A "one size fits all" approach to critical bleeding management may lead to unnecessary morbidity and mortality. For example, only a quarter of patients with massive bleeding in severe trauma or obstetric haemorrhage experience significant coagulopathy.[6] Viscoelastic haemostatic assays (VHAs) as part of the PBM paradigm support the rapid identification of patients with coagulopathy at the point of care.[6] Moving away from ratio-based product transfusion to targeted individualised treatment during critical bleeding rationalises blood product use which, as a sequela, reduces the risk of transfusion-related morbidity and mortality. This is important as short-term risks of transfusion include product-related risks, volume-related risks and iatrogenic injury.

VHAs provide clinicians with an evidence-based tool to better approach GDBM in critical care and perioperative settings. The assays provide real-time diagnostic data on the presence or absence of coagulopathy, the likely causes, as well as the effectiveness of interventions. By empowering clinicians to use evidence-based methods to guide bleeding management and transfusion, anaesthetists can improve patient outcomes and support a more sustainable health system.[17] Despite the known benefits of PBM and particularly the use of VHAs, the greatest challenge is the translation from evidence-based research to clinical anaesthetic practice.[18]

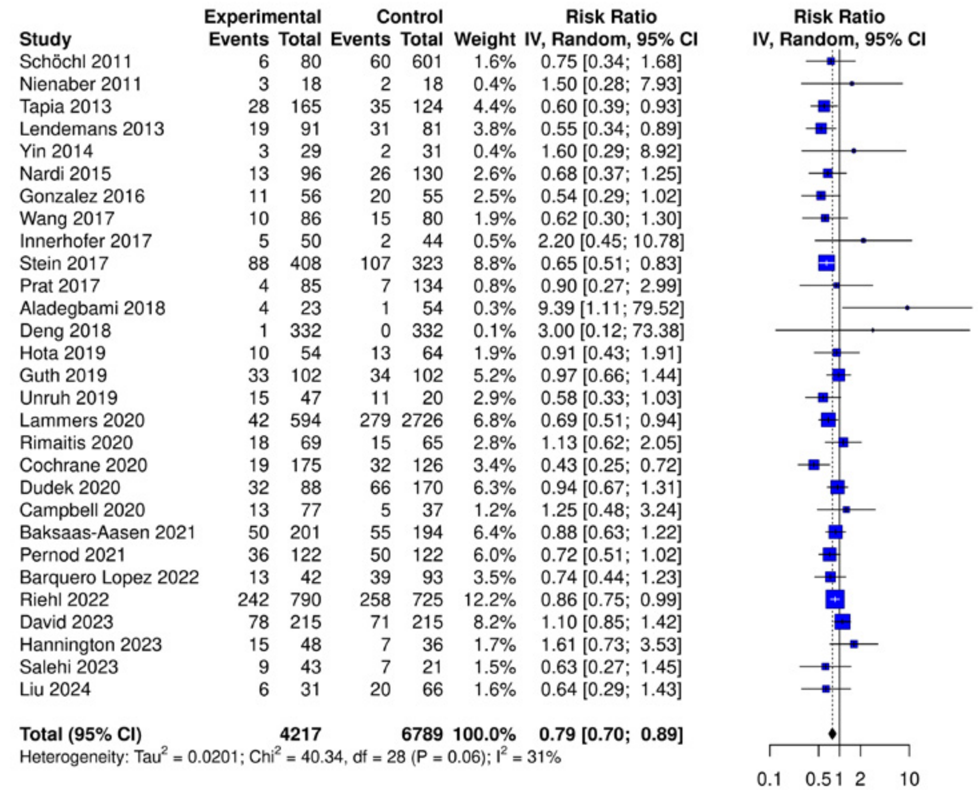
While managing intraoperative bleeding is complex, there is a growing body of evidence and numerous guidelines providing clarity for anaesthetists on VHAs and treatment.[19-26] Timely and effective treatment requires a critical care physician to lead multidisciplinary collaboratives.[27,28] These episodes can occur with varying degrees of complexity and urgency. Given the potential for poor to catastrophic outcomes, therapeutic inertia is not an option.

The challenges of implementing change initiatives vary widely, as unique cohorts and contexts require specific implementation activities to achieve success. This article aims to assist local implementation initiatives of GDBM with VHAs by defining clear, translatable strategies. We have included clinical examples where relevant but have chosen not to name any specific site. All examples are from Australia.

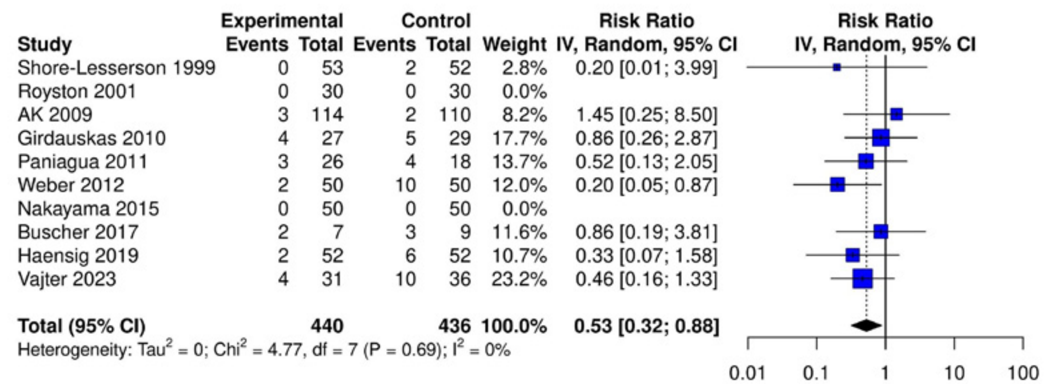
EVIDENCE FOR VHA TESTING IN GDBM

In 2023, the Australian NBA recommended that all hospitals establish a major *haemorrhage* protocol to manage critical bleeding effectively, shifting away from a massive *transfusion* protocol, highlighting the importance of individualised response to the type of bleeding and identifying specific haemostatic defects.[9] This name change emphasises the evolution away from transfusing large volumes of blood products, towards early intervention with goal-directed therapies to reduce reliance on transfusion. VHA-guided GDBM is an effective strategy to address blind large volume transfusion and to avoid complications and poorer outcomes associated with the additive negative effect of bleeding and transfusion.[6] Together, transfusion associated circulatory overload (TACO), transfusion-related acute lung injury (TRALI), and the immune-modulating effects of transfusion account for more than two-thirds of transfusion-related mortality, with the main culprits being plasma-rich products.[6,29] In non-cardiac and cardiac surgery, there is considerable variation in intraoperative blood transfusion practice, both among clinicians and across healthcare organisations. These differences cannot be explained by patient preference, patient cohort, or disease severity.[30] Intraoperative red blood cell transfusion in coronary surgery is associated with increased mortality.[31] A growing number of randomised controlled trials show reduced morbidity and mortality with GDBM, particularly in cardiothoracic surgery where transfusion is common (Figure 1). Ensuring that patients only receive necessary blood product transfusion minimises these risks.

Figure 1. Effect of VHA on mortality in severe trauma and cardiovascular/lung transplant/ECMO surgery – meta-analysis



A. Trauma



B. Cardiac

Randomised controlled trials across trauma (Figure 1a) and cardiac surgery (Figure 1b) demonstrating the reduction in mortality risk ratios when GDBM with VHA is applied. Information sourced from Görlinger et al. (2024),[32] Görlinger et al. (2024),[33] Görlinger et al. (2025)[34]

Clinicians who have access to VHAs as part of their practice describe working without this guidance as "managing a major haemorrhage with a blindfold" (personal communication from a senior anaesthetist, 7 March 2018). Taking the blindfold off allows the perioperative clinician to identify which deficit(s) may be contributing to coagulopathic bleeding, such as residual heparin, hypofibrinogenemia, platelet dysfunction, decreased contribution of extrinsic or intrinsic coagulation factors, or hyperfibrinolysis.

Using algorithmic tools with VHAs provides a decision support matrix (Figure 3). The first question to be answered is: Does the patient have clinically significant bleeding? If yes, the next step is to identify early hyperfibrinolysis (EXTEM A5/CRT A10) and fibrinogen (FIBTEM A5/CFF A10). Once this has been corrected, the next step is to consider and correct platelet (EXTEM A5/CRT A10) contribution to clot quality, and finally, coagulation factor deficits. Addressing fibrinogen early in a decision support matrix is supported by a 2024 study which concluded fibrinogen replacement can reduce the EXTEM CT independent of coagulation factor repletion (fresh frozen plasma (FFP) and/or prothrombin complex concentrate (PCC)).[35] This vertical algorithm uses a sequential approach and requires the clinician to check the treatment effect before considering additional blood product transfusion where appropriate. The stepwise strategy of factor correction can significantly reduce patient exposure to unnecessary blood products, namely FFP and PCC, and may reduce thrombotic risk and optimise resource utilisation.[35,36,37]

Fibrinogen can be replaced with either fibrinogen concentrate (FC) or cryoprecipitate. In Australia, cryoprecipitate is commonly used as a first-line agent for fibrinogen replacement and importantly it contains additional factors other than fibrinogen, such as Factor VIII, Factor XIII, von Willebrand factor and fibronectin. However, off-label prescription of FC is increasing in Australia due to its ease of use. This is especially where fibrinogen levels are subtherapeutic and associated with bleeding, where the delay awaiting cryoprecipitate is considered unsafe. It is essential to understand the key role of fibrinogen in critical bleeding, as it is the most abundant coagulation factor and the first to fall during a major haemorrhage. Additionally, addressing fibrinolysis early in a decision support bleeding management algorithm enables effective fibrinogen replacement.

The potential cost benefits for local health systems that implement PBM as their standard of care have been demonstrated. A Western Australian study of four hospitals showed $18.5 million in savings on blood product acquisition and an additional $80-100 million in activity-based cost savings over a five-year period.[38] Additionally, a Queensland hospital implemented a tailored bleeding management protocol based on VHA testing, which resulted in a decrease in the acquisition cost of blood products by more than $1 million in 15 months, alongside reductions in reoperations for bleeding, superficial chest and leg wound infections, as well as a 12 per cent reduction in postoperative length of stay.[39] These results are supported by a more recent prospective cohort study that demonstrated bleeding patients had 1.76 (CI, 1.64–1.90) times higher costs associated with their cardiac surgery than those without a bleeding event.[39,40]

A recent life-cycle analysis from Great Britain addressing transfusion-related environmental impact found that the majority of total CO_2 emissions from packed red blood cell transfusions were related to transportation costs.[15] Given the significant geographical challenges in Australia and New Zealand, these emissions costs are anticipated to be amplified.[15] Moving towards net-zero and more sustainable healthcare models, GDBM offers a key point-of-care strategy for clinicians to reduce healthcare-related emissions.

GUIDELINES SUPPORTING GOAL-DIRECTED BLEEDING MANAGEMENT

There are numerous clinical practice guidelines (CPGs) available for critical care clinicians to help support decision-making around appropriate therapies and strategies to manage bleeding (Table 1). In 2021, the Society of Thoracic Surgeons (STS), Society of Cardiovascular Anaesthesiologists (SCA), American Society of ExtraCorporeal Technology (AmSECT) and Society for the Advancement of Patient Blood Management (SABM) came together to recommend that, "Goal-directed transfusion algorithms that incorporate point-of-care testing, such as with [VHAs], are recommended to reduce peri-procedural bleeding and transfusion in cardiac surgical patients (class I, level B-R)".[24] In 2023, the European Society of Anaesthesiology and Intensive Care recommended "the use of intervention algorithms incorporating predefined triggers and targets based on coagulation monitoring to guide individualised haemostatic intervention in the case of perioperative bleeding".[41] That year, the European Society of Cardiologists also recommended the

use of "point-of-care diagnostics for guidance of blood component therapy, when available" as a class I recommendation.[23] In 2019, guidance for obstetric management was published in a global consensus statement by the Network for the Advancement of Patient Blood Management, Haemostasis and Thrombosis (NATA), which recommended the use of "viscoelastic haemostatic tests to guide appropriate, goal-directed use of haemostatic blood components and pro-haemostatic agents (1B)".[42]

These and other recommendations are highlighted in Table 1.

Table 1. Recent GDBM guidelines

Year	Guideline
2025	AAGBI Association of Anaesthetists guidelines: The use of blood components and their alternatives.[19]
2025	Cardiac surgical bleeding, transfusion, and quality metrics: Joint consensus statement by the Enhanced Recovery After Surgery Cardiac Society and Society for the Advancement of Patient Blood Management.[43]
2024	EACTS/EACTA/EBCP Guidelines on cardiopulmonary bypass in adult cardiac surgery.[21] (Incorporates bleeding management strategies.)
2024	Patient blood management guideline for adults with critical bleeding. Medical Journal of Australia (MJA).[44]
2023	The European guideline on management of major bleeding and coagulopathy following trauma: sixth edition.[45]
2022	Management of severe perioperative bleeding: Guidelines from the European Society of Anaesthesiology and Intensive Care. Second update 2022.[22]
2022	ESC Guidelines on cardiovascular assessment and management of patients undergoing non-cardiac surgery: Developed by the task force for cardiovascular assessment and management of patients undergoing non-cardiac surgery of the European Society of Cardiology (ESC). Endorsed by the European Society of Anaesthesiology and Intensive Care (ESAIC).[23]
2022	International Federation of Gynaecology and Obstetrics (FIGO) recommendations on the management of postpartum haemorrhage.[46]
2021	STS/SCA/AmSECT/SABM: Update to the clinical practice guidelines on patient blood management.[24]
2020	Guidelines for the management of adult acute and acute-on-chronic liver failure in the ICU: cardiovascular, endocrine, haematologic, pulmonary, and renal considerations.[47]
2019	Patient blood management in obstetrics: prevention and treatment of postpartum haemorrhage. A NATA consensus statement.[42]
2018	The use of viscoelastic haemostatic assays in the management of major bleeding: A British Society for Haematology guideline.[48]
Journals: European Association for Cardio-Thoracic Surgery (EACTS), European Association of Cardiothoracic Anaesthesiology (EACTA), European Board of Cardiovascular Perfusion (EBCP), National Health Service (NHS), European Society of Anaesthesiology (ESA), Medical Journal of Australia (MJA).	

TRANSLATING GUIDELINES INTO CLINICAL SUCCESS

While guidelines provide a useful foundation to support clinician decision-making, the process of changing practices and attitudes towards GDBM is complex and must be delivered with both empathy and rigorous logic.[27,49-51] Senior clinicians must first "unlearn" strategies they were taught as students. During the period of change they may temporarily experience a feeling loss of competence, clarity and control. Transition through this process can be facilitated by the solutions we propose here.

These include learning VHAs as a single concept, independent of the testing platform, and recognising and understanding the key role of correcting fibrinogen deficits early. By combining the two common VHAs (thromboelastography (TEG) and rotational thromboelastometry (ROTEM)) into a single learning concept, clinicians can feel confident using both VHA technologies across different units. Uptake of VHA-guided GDBM requires recognition that the two distinct viscoelastic haemostatic measuring instruments (ROTEM and TEG) are common across Australian sites. Some hospitals currently have both technologies in different subspecialties – for example, obstetric departments may favour technology with highly accurate dual inhibited fibrinogen assessment, while cardiac departments may prioritise assessment of platelet function. Therefore, VHA must be taught as an all-encompassing subject.

We propose a shift in the way VHA-guided GDBM is taught, and how algorithm graphics are depicted and used. This new paradigm requires:

1. Teaching knowledge and skills around VHA interpretation as a "general concept".
2. Applying an understanding of the "general concept" of VHAs to appreciate the strengths and weaknesses of each test.
3. Understanding the key role of addressing fibrinogen deficiency early.[36]

The structure of the algorithm is very important to simplify bleeding management into a stepwise approach following a physiologic process.[35,53] These algorithms are devised for clinical use and as teaching tools to support ease of comprehension and simulation training. They are also being developed into tools, such as mobile applications (for example, the TEGRotem app).

Figure 2. General surgical and obstetric ROTEM and TEG goal-directed bleeding management algorithm – product details simplified

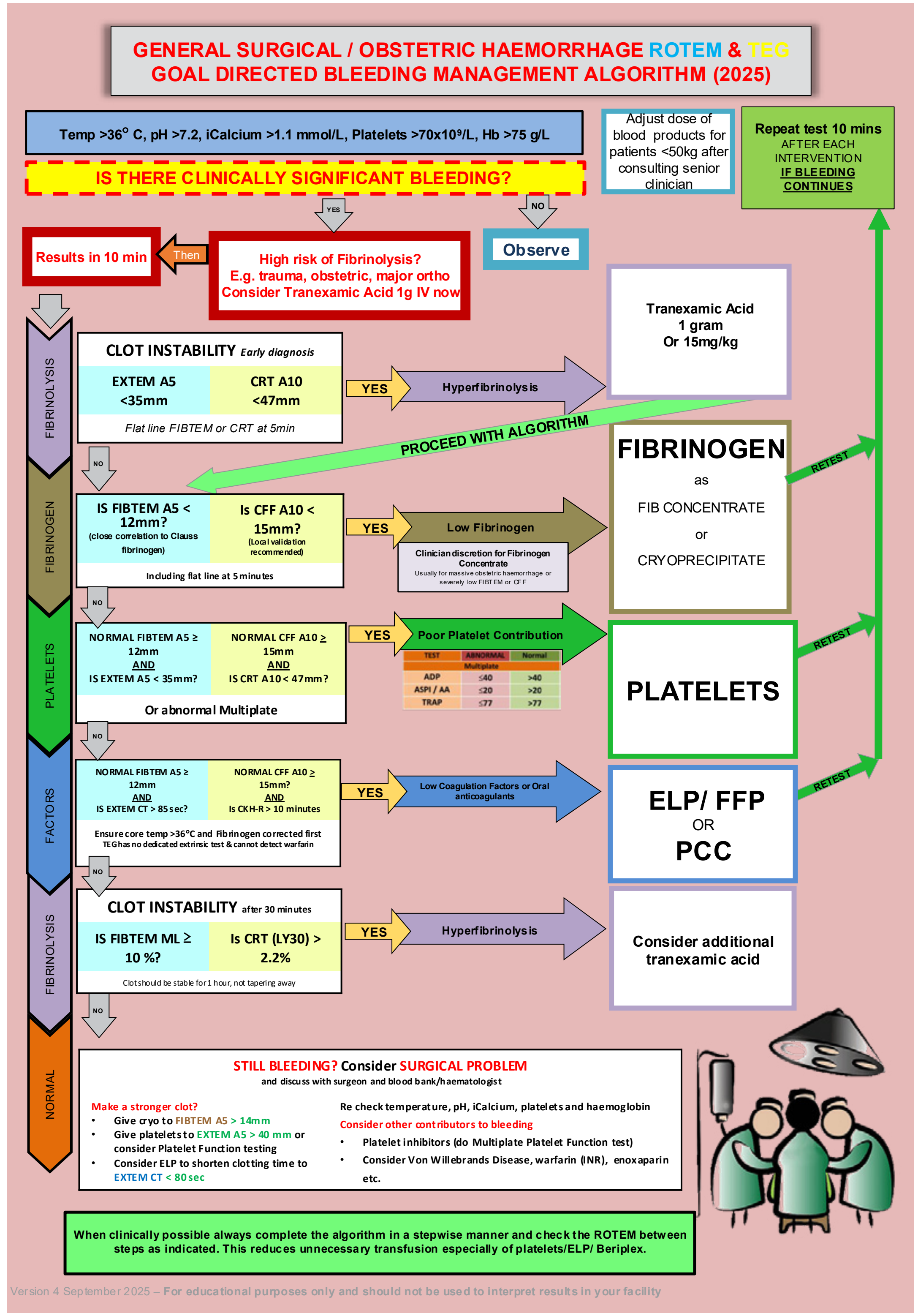
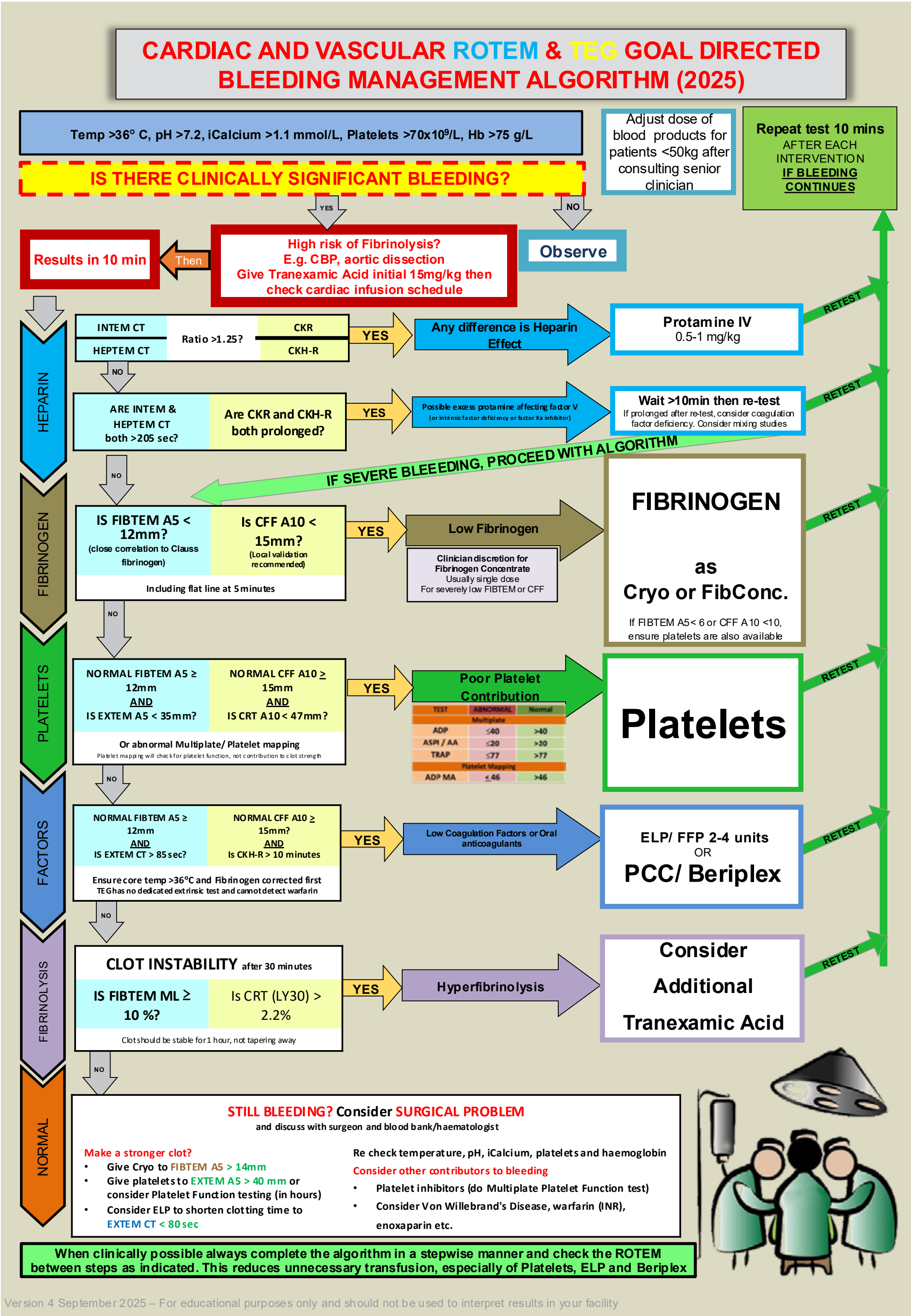


Figure 3. Cardiac and vascular ROTEM and TEG goal-directed bleeding management algorithm – product details simplified



These tools form an important strategy to support clinician decision-making, as managing intraoperative bleeding is technically and contextually complex.[30] However, there is a significant body of evidence and numerous guidelines providing clarity for critical care physicians on diagnostic assays and treatment.[16,19,25,43,45,53]

GDBM during major haemorrhage requires critical care physicians to make timely, effective treatment decisions and to lead a multidisciplinary collaborative effort.[27,28,54-57] These episodes can occur with varying degrees of complexity and urgency at one or many timepoints during the critical bleed. However, critical care physicians may either lack confidence in their skills to lead multidisciplinary teams, or not be aware of the latest evidence-based recommendations. They may not have access to the most appropriate diagnostic assays, have the knowledge or skills to interpret assays, or have access to the most appropriate blood products.[27,58-60]

By considering hurdles clinicians face in the implementation of evidence in GDBM and VHA, strategies to overcome these barriers emerge.

THE SCIENCE OF CHANGE MANAGEMENT

Variable compliance with evidence-based recommendations and guidelines is of great concern to the clinical community.[51] Implementation science is focused on the promotion of methods to recognise, understand, and develop processes that can support practice improvement, and ultimately patient outcomes.[18] The abundance of research on the management of bleeding demonstrates the necessity of uncovering new evidence and improved treatment strategies.[18] Clinicians are, however, less efficient at translating the evidence into practice. This continued challenge in efficiently translating knowledge into action can result in frustration, ineffective care, or potentially harmful care, along with individual and organisational health inequity.[61] It is important to recognise that "unassisted" translation of knowledge into practice is not efficient, effective, economically viable, or sustainable.[61] Implementation strategies or activities to support the translation of knowledge into practice are rarely discussed during medical training or in guidelines by societies or colleges.

To introduce new practices, a clinician or group of clinicians must:

1. Decide if the evidence is compelling and relevant enough to integrate it into their practice.
2. Convince peers and administrators that supporting this initiative is worth it as it will improve patient outcomes, and that the associated costs can be met.
3. Implement activities to make change, with no guarantee that their peers will accept it.[62]

These are significant challenges and may in fact become overwhelming barriers for clinicians, departments and healthcare organisations attempting to implement evidence-based change initiatives.

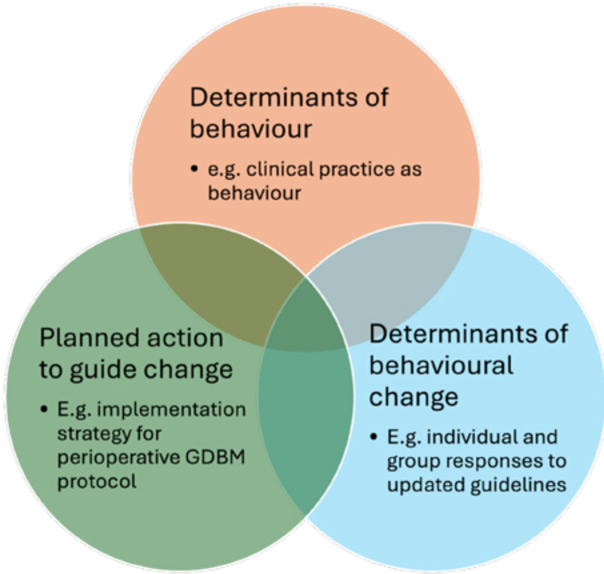
Analysing behaviour – a moment of self-reflection

Clinical practice is a form of behaviour. Therefore, understanding the influences on existing behaviours, in the context in which they occur, is necessary to "change practice". Clinical practice as a behaviour in the perioperative environment is part of a social process with complex relationships, where the dyad relationship between surgeon and anaesthetist is of particular importance.[57] Clinical practice behaviours can be described, categorised, and understood with theories, frameworks, and models.[63] Understanding behaviours in the relevant context supports the selection of activities or interventions that are likely to be effective in each situation, consequently increasing the probability of translating knowledge into practice.[57] This is of particular importance for perioperative clinicians, where patient cohorts, consultant groups, and healthcare contexts are diverse, yet unique, requiring targeted implementation activities to achieve successful practice improvements.

Frameworks, models, and theories

Frameworks, models, and theories can be categorised into those that focus on psychological barriers and facilitators of change, and those that focus on change itself (Figure 4). These will be explored in more detail throughout the article with clinical examples.

Figure 4. Frameworks



Determinants of behaviour

The theoretical domains framework (TDF) helps to identify and define cognitive, affective, social, and environmental influences on clinicians' behaviour in relation to implementation of evidence-based recommendations. This first step identifies and categorises given barriers and/or facilitators to behaviour.

Determinants of behavioural change

The capability, opportunity, motivation, behaviour model (COM-B) describes how capability, opportunity, and motivation interact to positively, or negatively, influence behaviour. Capability determines the psychological and physical capacity to adopt or change a particular behaviour. Opportunity identifies external factors that make a behaviour possible. Motivation covers the thought processes that direct changes in behaviour. Both capability and opportunity can influence motivation. While motivation determines whether clinicians will or won't adopt a particular behaviour, capability and opportunity determine whether a clinician can or can't adopt it.[27,64]

Provide planned action to guide change

The knowledge to action (KTA) framework provides planned guidance for implementing change (Table 2).[62]

Table 2. Knowledge to action framework

Action phases	Examples
Correlating evidence to address identified clinical concerns	Audit of current practice Literature reviews
Understanding barriers to and facilitators of change implementation	TDF and COM-B, surveys, interviews, working groups
Developing and introducing evidence-based strategies and/or technology	VHAs algorithms, quality assurance protocols, live streaming of VHA results
Developing intervention activities to support behaviour change and the uptake of evidence	Education sessions Simulation training procedures, training packages
Monitoring use of the intervention	Number of VHAs performed Compliance with algorithm, surveys, interviews Real-time changes with VHA parameters against treatment
Evaluating clinical outcomes	Auditing of blood product utilisation, blood loss, length of stay (ICU/hospital), leg/chest wound infection, reoperation rates for bleeding
Ensuring sustainability of the intervention	Development of long-term interest groups within departments for continual improvement Embedding VHA monitoring as standard agenda items within PBM committee meetings

The guidance developed from these models and frameworks, supports clinicians in controlling variables that increase the likelihood of positive change.

FACILITATORS AND BARRIERS TO BLEEDING MANAGEMENT PRACTICE IMPROVEMENT

There is an emerging body of literature addressing adherence to evidence-based bleeding management strategies, variability of transfusion practice, and the role of clinician behaviours in the perioperative environment.[27,28,54-57,59,60] This literature demonstrates clinicians may not always have the capability and opportunity to provide evidence-based bleeding management, even when they perceive patients would benefit from such interventions.[58-60]

Complexity

In critical bleeding scenarios, clinicians can find themselves overwhelmed with multiple competing priorities. The cognitive load of calling upon a plethora of existing and emerging evidence can be difficult even among experienced clinicians. One solution is the use of contextually relevant algorithms for bleeding management with a step-by-step matrix.[65]

Standardised practice using decision support tools (such as algorithms, guidelines and procedures) supports clinicians' ability to manage bleeding and is an accepted philosophy for the provision of high-quality, consistent, and safe healthcare delivery. Initially, evidence must be contextualised into tools that provide behaviour regulation through standardisation, prompts, reinforcement, and enhancement of appropriate routines.[27,66-69] Flexibility in decision-making must be woven into standardised tools, as rigid application of guidelines is not always appropriate for every patient or context.[27,70]

Standardised algorithms (see Figures 2 and 3) assist clinicians in focusing on stepwise methods to correcting coagulopathy.[22] Such algorithms should be made available at key points of care – for example, in emergency and cardiac theatres – as well as online for staff members to easily access in remote settings. In one tertiary centre, such algorithms are made accessible via QR codes on staff ID badges to assist in emergency scenarios. Translating evidence into contextually relevant decision support tools, guidelines, and procedures is time-consuming. The burden of creating these is often left to innovators who possess the "capability" and "motivation", and who extend themselves to create "opportunities". Standardisation should be supported at individual, departmental, organisational, and national levels, with existing algorithms from centres running successful GDBM programs shared widely for adoption by clinicians at new sites.

Strengths and weaknesses of individual VHAs also need to be understood. One weakness is that the TEG 6 global haemostasis cartridge does not have a pure tissue factor activated test for the extrinsic pathway as this test also contains kaolin and it can also be affected by heparin.[71] Consequently, due to limitations of the available information, clinicians may unnecessarily give PCC products without specific evidence that patients are devoid of extrinsic clotting factors – this is not GDBM. Similarly, neither the global haemostasis cartridge of TEG 6s nor ROTEM Sigma system gives a comprehensive picture of platelet function. Therefore, their use in conjunction with a specific platelet test, such as the TEG platelet ADP test or the Multiplate ADP, TRAP and AA (aspirin) test, is useful in the presence of platelet inhibitors. The complexity of these tests is substantial; however, understanding VHA holistically is essential if we are to progress GDBM.[53,71,72]

Human factors can confound even the best clinical trials. Despite the known benefits and demonstrated accuracy of results, such as the FIBTEM correlation with Clauss fibrinogen,[73] randomised controlled trials may be confounded by human factors and other barriers discussed in this article.[74]

Challenges in teaching cross-disciplinary evidence-based medicine

Clinicians and other healthcare workers across a myriad of disciplines may be involved in major haemorrhage situations. While each craft group brings specific skills or expertise to such scenarios, cross-discipline education ensures these teams work effectively with a shared mental model. Human factors in healthcare can have both profoundly advantageous or disastrous influences on teams. Dysfunctional relationships and human error causes up to 50 per cent of adverse events in a healthcare context.[75-78] Cross-discipline training programs involving key perioperative clinicians help capture the complexities of bleeding management scenarios, supporting multiple disciplines to "speak the same language".[27,79]

Long-term change includes early learning at key stages of development as a clinician. By embedding the concept of PBM beginning in medical school and then expanding into VHA testing and advanced GDBM in specialist training programs, we can capture clinicians at key stages of their learning experience. A shared mental model of GDBM (and the role of VHA in achieving this) needs to be multidisciplinary. Figure 5 highlights key stakeholder groups that need to share this mental model in an Australian context, but is by no means exhaustive.

Figure 5. Key group stakeholders

CICM: College of Intensive Care Medicine, RACS: Royal Australasian College of Surgeons, RANZCOG: Royal Australian and New Zealand College of Obstetricians and Gynaecologists, ACEM: Australasian College for Emergency Medicine, RACP: Royal Australasian College of Physicians, ACORN: Australian College of Perioperative Nurses, ACM: Australian College of Midwives, ANZCP: Australian and New Zealand College of Perfusionists, ACNP: Australian College of Nurse Practitioners, ACCCN: Australian College of Critical Care Nurses, MDANZ: Medical Deans Australia and New Zealand, CPMC: Council of Presidents of Medical Colleges, ANZSBT: Australian and New Zealand Society of Blood Transfusion, RCPA: Royal College of Pathologists Australia.

By incorporating these concepts into the curriculum of these institutions and colleges, we can help instil evidence-based blood management practice in the next generation of clinical leaders. However, the group of key stakeholders is large and heterogeneous, which presents challenges in reaching different craft groups. This highlights the need for flexible and innovative ways of delivering education tailored to the needs of individual groups or practitioners.

Within anaesthesia itself, a recent study in the United States showed there was a significant gap in transfusion medicine knowledge.[80] Teaching evidence-based medicine (EBM) is challenging; however, including key concepts from pre-clinical stages of student learning can lead to long-term behavioural change in students.[81-83] Systematic reviews have shown there is a gap between EBM and clinical practice, while also highlighting that a variety of teaching strategies are required to embed concepts in developing clinicians.[81] There is insufficient evidence to support one teaching style over another, but what is known is that teaching and assessment of key concepts needs to be interactive and multifaceted to achieve better clinical implementation of EBM.[81]

Discipline-specific training provides the addition of context to address patterns of coagulopathy that are unique to specific cohorts.[66,67,69] Multidisciplinary and multidimensional training supports the team, develops a common language and shared mental model, and removes dependence on the attributes of individuals.[66,70,84-86] This layered training exposes clinicians to unpredictable variations of practice, miscommunications, and misunderstandings.[66,70,85-87]

Multidisciplinary clinicians working together are considered to be a "team of experts".[87] Unfortunately, this does not necessarily translate to multidisciplinary clinicians being "experts at teams". Often, there may be unacknowledged tension amongst team members with other social motives existing that involve personal working relationships (e.g. anaesthetists relying on surgeons for private work), where familiarity can be perceived as shared trust but may actually involve dysfunctionality.[57]

To provide another example, within the cardiac surgical context there is no stable centre of authority; the leadership role is determined by the clinical priority at any given time. Different specialties are motivated by varied objectives, all of which are valid and appropriate. Drawing all the threads from each team member together to make informed decisions cannot be learned from a book or didactic lecture.

Communication – variability in non-technical skills

Anaesthetists are highly qualified and accomplished clinicians who possess "hard skills", or technical skills, that require significant cognitive intelligence, extensive medical knowledge, and skills learned through training and education.[88] Considerably less attention and formal training is given to the development of "soft skills", or non-technical skills.[57,79,89-91] Soft skills are often inherent, perceptive, and social personal resources that support effective communication and collaboration.[92] Literature suggests clinicians understand the implications of non-technical skills, but not necessarily how to improve them in real-world practice.[57,79,89-91]

Individuals learn in different ways, but everyone can still learn a variety of skills and concepts through various learning styles. Traditional teaching methods, such as didactic teaching, are being increasingly superseded by more interactive methods, for example, problem-based learning and simulation-based medical education (SBME).[81,93,94] However, traditional methods still play a role, especially in teaching basic sciences. Evidence shows that reinforcing didactic teaching with a variety of alternate training methods leads to better practice of EBM, and both technical and non-technical skills.[81,82,94]

Through immersive roleplay, SBME provides a transformative method of upskilling clinicians in both technical and non-technical management of crises.[93] SBME has been shown to increase proficiency in the management of time-critical, low-frequency, and high-morbidity conditions. However, SBME can be resource- and time-intensive to implement, particularly with increasing levels of fidelity to clinical practice. While high-fidelity simulations are ideal, even low-fidelity SBME can improve a learner's skills and facilitate the development of non-technical skills.

Psychosocial barriers and social influences

Change can be daunting, and clinicians looking to implement new practices can face an uphill battle in changing departmental culture. Established clinicians must first "unlearn" what they were taught and still believe about bleeding management. Clinicians may have reasonable reservations regarding new evidence or technologies. Their views should be acknowledged, and robust discussion within departments should be supported as part of any change process. However, some reservations may be based on outdated evidence or may not withstand scrutiny. While these reservations can be challenging to address, forming groups of interested clinicians can help encourage change. Once a critical mass of clinicians has adopted a new approach, improved patient outcomes can become apparent and widespread change becomes possible. Clinical sites with experience implementing VHA provide an invaluable resource for other individuals or small groups of clinicians. Mentoring as an aide in the implementation of evidence-based practices has been used in other disciplines.[95] Learned experience, particularly regarding unforeseen and unexpected barriers, can help streamline the incorporation of VHA and GDBM at new sites. The authors of this article have mentored many new hospitals as they initiate GDBM programs.

Clinical setting, environment and cost

Governance and resourcing inconsistencies between regional and metropolitan or between public and private hospitals may influence the ability to implement VHA as a standard of care.

Unfortunately, the mere existence of standardised decision support tools and necessary technology is not sufficient for change. Clinical environments need to foster ease of access to resources for healthcare workers to use in crises. When implementing GDBM protocols, clinicians need to be mindful of physical barriers or challenges – for example, the physical distance from the bedside to where VHA testing technology is located. The location of equipment is important to consider when introducing VHAs, as learned by one Australian hospital where they initially installed the machines in the laboratory, geographically distanced from the bedside, before realising this created undue burden. That site has recently moved the VHA device to the point of care. However, this may not be a barrier at other sites where workflows may allow VHA instruments to reside in the laboratory and be managed by laboratory staff. The use of technology, such as livestreaming results of VHA tests to individual theatres or to bedside devices, can help address these resourcing issues but requires support from hospital administrators and digital technology teams. Additionally, confidentiality around patient information must be considered and addressed.

Other aspects of the clinical environment are easier to manage. For example, standardised algorithms should be conveniently available to clinicians at points of care, either physically or electronically. As previously described, training teams using SBME can help ensure clinicians know where and how to access decision support tools in a crisis.

Varied cost models exist and need to be negotiated based on context. In some jurisdictions, the Local Health Networks (LHN) may have a VHA service provided by contracts delivered through their pathology providers. The cost of VHA in other jurisdictions may be absorbed by the LHN, including the costs to purchase machines, consumables and quality assurance programs. Unlike pathology providers, LHNs in most areas cannot access financial rebates through the Medicare benefits schedule for VHA testing. Furthermore, complicating the financial barrier, direct savings through reduced blood product use may not be from the LHN budget. Additionally, a VHA service driven by clinicians places additional workload on doctors, nurses and perfusionists at the point of care to manage the device, consumables and quality control programs, all with a cost and no direct local financial incentive.

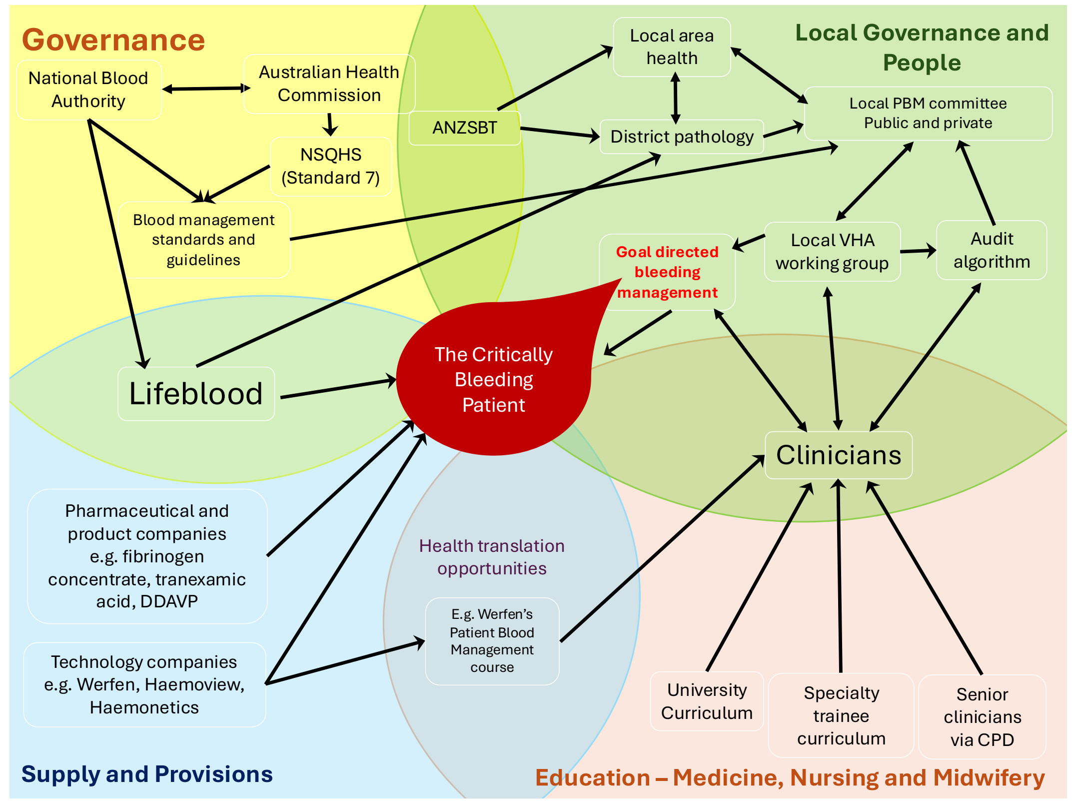
Governance

In Australia, the NBA manages and co-ordinates the supply of blood products and services. The Australian Health Commission provides the National Safety and Quality Health Service (NSQHS) standards which ensure organisations provide a consistent quality of care – defined in Standard 7 (Blood Management Standard).[91] The Australian Red Cross Lifeblood is the sole provider of domestic blood and blood products within Australia (see Figure 5). Disparate funding systems exist across Australian public and private healthcare. Under the National Blood Agreement, blood products are funded 63% by the Commonwealth and 37% by the states and territories. Queensland and New South Wales have passed on the 37% cost to individual public (but not private) healthcare services, while other states and territories may not pass on the cost. In New Zealand, the New Zealand Blood Service is responsible for the governance and performance of functions in relation to blood and controlled human substances, and hospital and healthcare services are responsible for 100% of the cost of blood products. Passing on the partial or full cost of blood products to the hospital and healthcare services will be an additional driver as a financial incentive to implement evidenced-based strategies.

Historically, blood product governance and oversight at local levels have been guided by haematologists predominantly working within laboratory settings. This structure may present barriers to the implementation of VHAs into routine practice, as haematologists may have varied experience and interest in the use of VHAs in managing critical bleeding. Concerns from haematologists may stem from loss of oversight of the testing modalities used in GDBM as they often reside outside laboratories. Encouragingly, VHA testing platforms are increasingly integrated into laboratories with automated streaming to pathology systems, enrolment in Royal College of Pathologists of Australasia quality assurance programs, and better oversight for batch/lot consumables.

Local governance involves multidisciplinary clinicians with an interest and involvement in both PBM and the judicious use of blood and blood products participating in local PBM committee meetings and quality initiatives (Figure 6). These committees provide organisation-wide oversight for the implementation of quality improvement systems. This includes ensuring best practice procedures for managing patients' own blood, appropriate clinical use of blood products, managing the availability and safety of blood products, and minimising wastage. This is achieved through ongoing quality activities to monitor and address outlying practice, updating procedures, algorithms, training manuals, documentation of education strategies and presentation of audit results. During the implementation of VHA into standard of care, governance should be provided by the local PBM committee to ensure practice change is safe, appropriate, efficient, and effective.

Figure 6. Systems map for the critically bleeding patient



In Australia, NSQHS Standard 7 (Blood Management) requires that facilities provide evidence-based care and implement strategies that improve blood management, including haemovigilance to monitor and evaluate the safety of blood transfusion and blood product wastage.[96] This must be facilitated through governance groups, such as PBM committees, which bring together team members from the laboratory, specialist haematologists, critical care physicians, and nursing staff to collaborate and address gaps or outliers in practice and benchmarking outcomes. This is particularly important in larger facilities that have laboratories and blood banks on site. These national standards further stipulate that clinicians should determine clinical need for products and minimise the inappropriate use of products, which can be achieved by integrating VHAs.

Organisational support

There is little uniformity in navigating the delivery of care, both within and between public and private systems and organisations.[27,50,97] Unfortunately, these systems are growing more complicated, measures of success are increasingly vague and often without an apparent relationship to patient outcomes, and all within an atmosphere of healthcare crisis. Healthcare organisations need to stay within budget, where rationing, rationalising, cost-effectiveness, and "creating efficiencies" are buzzwords. This places clinicians in the challenging position of advancing evidence-based practice while simultaneously understanding and navigating competing organisational priorities and external agencies to achieve their goal. The practicalities, or simply the ability to "find a way", often appear to be the most difficult; a strong motivation for practice improvement can still drive clinicians forward, even when they are limited by a lack of managerial support or resources.

A good understanding of site-specific restrictions and considerations is vital for the successful implementation of VHA and GDBM protocols. There are likely to be nuances related to how certain blood products are accessed across blood banks as well as variations in institutional practices. For example, some sites may require haematology specialist approval for certain blood products (i.e. fibrinogen concentrate), some products may only be approved for specific indications, and some facilities may not have timely access to all blood products.

In recent years, a regional teaching hospital in Australia attempted to implement VHA and standardised algorithms for GDBM. However, the anaesthetist involved had no prior experience in implementing a major project and was facing challenges, from organisational through to departmental levels. This was overcome through mentorship from a clinician from another metropolitan hospital that had successfully implemented the same intervention. The mentor was able to guide the project lead through logistical steps and pre-emptively identify and address barriers, while the project lead could provide the contextual knowledge and on-site expertise of key considerations specific to their facility. Such mentorship is currently ad hoc and relies on the mentor's good will and motivation.

Networks of clinicians who have been successful in implementing improvements are also useful. Sharing knowledge of barriers, and helping clinicians feel empowered to approach management and administrators, can simplify a process foreign to most healthcare practitioners. With GDBM and VHA, this may involve the formation of special interest groups within professional bodies such as ANZCA. These groups would function as a support mechanism, formalise mentorship, and provide an avenue to share knowledge and develop resources for use by individual sites or clinicians wishing to implement changes at their sites.

Continuing motivation and improvement

Despite initial enthusiasm, without continued motivation from healthcare providers, implementation of EBM can face ongoing barriers. Unless continued improvement in patient outcomes or other key performance indices (such as ICU or hospital length of stay) can be demonstrated, clinicians may become apathetic towards a particular innovation before it becomes standard practice.

Continued audit and feedback cycles are necessary processes to address these issues and at multiple organisational levels:

1. Convincing clinicians by demonstrating improved patient outcomes.

2. Convincing managers with appropriate resource utilisation.

3. Convincing administrators with cost savings.[27]

To be effective, audits need buy-in from perioperative teams.[98] Audit and feedback can be particularly relevant for anaesthetists and surgeons as they are often a highly driven and competitive group of clinicians. For example, a recent sustainability quality improvement project used site-specific and live data to motivate clinicians at a major American paediatric centre to reduce their greenhouse gas emissions, helping to reduce emissions by 87 per cent over a five-year period.[99]

Furthermore, audits provide an opportunity for working parties or PBM committees to regularly review their algorithms and decision support tools and update them as new evidence becomes available. Audit cycles can also identify new challenges faced by clinicians. For example, at one site with established VHA, algorithms were made available online, but hospital internet reception was poor and clinicians struggled to use electronic versions of decision support tools. This highlighted the need for easily accessible physical copies until digital infrastructure and connectivity were improved.

Audits should not be tokenistic. They should be meaningful and aimed at providing evidence of clinical benefit or highlighting areas of improvement. Reasons for non-compliance with a standardised algorithm may be valid – for example, clinicians may have deviated due to advice from haematology or a lack of timely access to certain products. Auditors should use these events as an opportunity to reflect on the utility of the algorithm objectively. By doing so, clinicians can be reassured that there is no threat to clinical autonomy.[98] Similarly, if audits show poorer patient outcomes or significant non-compliance with protocols, feedback should be received as an opportunity for improvement. Audits can also provide an avenue for junior doctors and nursing staff to engage in quality assurance within departments, offering valuable professional development opportunities.

Technological advances

Rapid technological advancements in the biomedical field provide ongoing challenges as well as opportunities in the implementation of EBM. Current technology is now laying the foundation of understanding for how PBM will evolve in the future as new VHAs are developed. Clinician feedback can assist developers in evolving and meeting complex challenges faced by clinicians. For example, incorporating point-of-care platelet function testing into existing VHAs, or the development of assays better able to assess the impact of newer anticoagulants, will help clinicians in providing better care.

Support from, and partnership with, industry is vital for the clinical implementation of new technologies. From early user training to ongoing maintenance and troubleshooting support, clinicians and industry can collaboratively improve patient outcomes. Furthermore, industry can learn from clinicians about new and emerging requirements as patient care evolves. For example, advances in mechanical circulatory support, as well as research into correlation coefficients in real clinical scenarios and outcomes, helped determine earlier detectable time points on VHA, with results available after five instead of 10 minutes.[100] This has assisted clinicians in treating coagulation issues earlier in a rapidly evolving bleeding scenario. In addition, industry can support logistical concerns, for example by providing secure web-based software so that the results of VHA testing can be accessed in real time by clinicians in theatres or resuscitation scenarios.

IDEAL IMPLEMENTATION TIMELINE

Figure 7 provides a theoretical timeline outlining actions involved in implementing GDBM, from the initial idea to implement VHAs to the successful use of GDBM. The timeline includes ongoing review after VHAs have been installed, with input from key stakeholders, including laboratory, senior clinicians, administration and users. Ongoing external quality control is also necessary for long-term quality assurance.

Figure 7. Implementation timeline: theoretical example

CONCLUSION

The use of GDBM to manage perioperative blood loss, bleeding and acquired coagulopathy is an important and effective strategy to improve patient outcomes. VHAs provide rapid identification of both the presence and cause of coagulopathy, and real-time feedback regarding the effectiveness of treatment. Critical care clinicians must lead multidisciplinary collaboratives to provide timely and effective treatment in dynamic situations. However, despite the known benefits of PBM and VHAs, the implementation of bleeding management treatment algorithms remains challenging. We propose that the best way to enable widespread holistic understanding is through cross-disciplinary education with stepwise, evidence-based decision support algorithms, treating fibrinogen first, and teaching available technologies (such as ROTEM and TEG) side by side. The challenges in implementing change initiatives vary widely, where unique cohorts and contexts require specific implementation activities to achieve success. Empowering clinicians to use evidence-based methods to guide bleeding management and transfusion can improve patient outcomes and support a more sustainable health system.

Appendices and further resources are available here: downs.com.au/rotemteg-project

REFERENCES

1. Thomson A, Farmer S, Hofmann A, Isbister J, Shander A. Patient blood management - a new paradigm for transfusion medicine? ISBT Sci Ser. 2009; 4(2):423-35.
2. Goodnough LT, Shander A. Patient blood management. Anesthesiology. 2012; 116(6):1367-76.
3. Shander A, Hardy JF, Ozawa S, Farmer SL, Hofmann A, Frank SM, et al. A global definition of patient blood management. Anesth Analg. 2022; 135(3):476-88.
4. Ozawa S, Isbister JP, Farmer SL, Hofmann A, Ozawa-Morriello J, Gross I, et al. Blood health: the ultimate aim of patient blood management. Anesth Analg. 2025.
5. Isbister JP. Comparing apples with oranges: Beliaev AM, Marshall RJ, et al. (2011). Clinical benefits and cost-effectiveness of allogeneic red-blood-cell transfusion in severe symptomatic anaemia. Vox Sang. 2012; 103(4):359-60.
6. Görlinger K, Kapoor PM. Massive transfusion/hemorrhage protocols versus goal-directed bleeding management: science gone eerie? Journal of Cardiac Critical Care TSS. 2024; 8(1):16-27.
7. Althoff FC, Neb H, Herrmann E, Trentino KM, Vernich L, Fullenbach C, et al. Multimodal patient blood management program based on a three-pillar strategy: a systematic review and meta-analysis. Ann Surg. 2019; 269(5):794-804.
8. World Health Organization. The urgent need to implement patient blood management: policy brief. 1st ed. [Internet] 2021. Available from: https://www.who.int/publications/i/item/9789240035744
9. National Blood Authority. National patient blood management implementation strategy [Internet]. 2017-2024. Available from: https://www.blood.gov.au/national-patient-blood-management-implementation-strategy-2017-2024
10. Sayers M, Centilli J. The aging of the donor base. Transfusion. 2012; 52(12):2717-22.
11. Hyde MK, Masser BM, Thorpe R, Philip AA, Salmon A, Scott TL, et al. Rethinking the role of older donors in a sustainable blood supply. Transfusion. 2025; 65(4):758-66.
12. Liang D, Pang Y, Huang J, Che X, Zhou R, Ding X, et al. Predicting postoperative blood transfusion in elderly patients undergoing total hip and knee arthroplasty using machine learning models. Risk Manag Healthc Policy. 2025; 18:1697-711.
13. Masubuchi T, Yoshitani K, Minami K, Yokoyama C, Tsukinaga A, Goto T, et al. Transfusion characteristics and hemostatic conditions in octogenarians undergoing emergency surgery for acute aortic dissection: A retrospective study. JA Clin Rep. 2020; 6(1):52.
14. World Health Organisation. Strategic framework for blood safety and availability 2016–2025. [Internet]. 2017. World Health Organization Regional Office for the Eastern Mediterranean. Available from: https://applications.emro.who.int/dsaf/emropub_2017_en_19608.pdf 2020
15. Hibbs SP, Thomas S, Agarwal N, Andrews C, Eskander S, Abdalla AS, et al. What is the environmental impact of a blood transfusion? A life cycle assessment of transfusion services across England. Transfusion. 2024; 64(4):638-45.
16. Dias JD, Levy JH, Tanaka KA, Zacharowski K, Hartmann J. Viscoelastic haemostatic assays to guide therapy in elective surgery: An updated systematic review and meta-analysis. Anaesthesia. 2025; 80(1):95-103.
17. National Blood Authority. Patient blood management guideline for adults with critical bleeding [Internet]. National Blood Authority Australia. 2023. Available from: https://www.blood.gov.au/patient-blood-management-guideline-adults-critical-bleeding
18. Wensing M, Grol R. Knowledge translation in health: how implementation science could contribute more. BMC Med. 2019; 17(1):88.
19. Shah A, Klein AA, Agarwal S, Lindley A, Ahmed A, Dowling K, et al. Association of anaesthetists guidelines: the use of blood components and their alternatives. Anaesthesia. 2025; 80(4):425-47.
20. Palomero Rodríguez MÁ, Jimenez FM, Ruiz IF, Casabon ES, Garcinuno SC. Evolution of the use of therapeutic fibrinogen concentrate in the massive bleeding guidelines. The Open Anesthesia Journal [Internet]. 2024 Aug.

18(1). Available from DOI:10.2174/0125896458339158240826043207
21. Casselman FPA, Lance MD, Ahmed A, Ascari A, Blanco-Morillo J, Bolliger D, et al. 2024 EACTS/EACTAIC guidelines on patient blood management in adult cardiac surgery in collaboration with EBCP. Interdiscip Cardiovasc Thorac Surg. 2025; 40(5).
22. Kietaibl S, Ahmed A, Afshari A, Albaladejo P, Aldecoa C, Barauskas G, et al. Management of severe peri-operative bleeding: guidelines from the European society of anaesthesiology and intensive care: second update 2022. Eur J Anaesthesiol. 2023; 40(4):226-304.
23. Halvorsen S, Mehilli J, Cassese S, Hall TS, Abdelhamid M, Barbato E, et al. 2022 ESC guidelines on cardiovascular assessment and management of patients undergoing non-cardiac surgery. Eur Heart J. 2022; 43(39):3826-924.
24. Tibi P, McClure RS, Huang J, Baker RA, Fitzgerald D, Mazer CD, et al. STS/SCA/AmSECT/SABM update to the clinical practice guidelines on patient blood management. J Cardiothorac Vasc Anesth. 2021; 35(9):2569-91.
25. Huang J, Firestone S, Moffatt-Bruce S, Tibi P, Shore-Lesserson L. 2021 Clinical practice guidelines for anesthesiologists on patient blood management in cardiac surgery. J Cardiothorac Vasc Anesth. 2021; 35(12):3493-5.
26. Faraoni D, Meier J, New HV, Van der Linden PJ, Hunt BJ. Patient blood management for neonates and children undergoing cardiac surgery: 2019 NATA guidelines. J Cardiothorac Vasc Anesth. 2019; 33(12):3249-63.
27. Pearse BL. Implementation of bleeding management in adult cardiac surgery programs in Australia. [dissertation on the Internet]. Brisbane: Griffith University; 2021. Available from DOI: https://dx.doi.org/10.25904/1912/4304
28. Hallet J, Sutradhar R, Jerath A, d'Empaire PP, Carrier FM, Turgeon AF, et al. Association between familiarity of the surgeon-anesthesiologist dyad and postoperative patient outcomes for complex gastrointestinal cancer surgery. JAMA Surg. 2023; 158(5):465-73.
29. Blumberg N, Refaai MA, Heal JM. Practical transfusion medicine. 6th ed. John Wiley & Sons. 2022. Chapter 13, Transfusion- induced immunomodulation p154-65. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119665885.ch13
30. Wilson MJ, Koopman-van Gemert A, Harlaar JJ, Jeekel J, Zwaginga JJ, Schipperus M. Patient blood management in colorectal cancer patients: a survey among Dutch gastroenterologists, surgeons, and anesthesiologists. Transfusion. 2018; 58(10):2345-51.
31. Vlot EA, Verwijmeren L, van de Garde EM, Kloppenburg GT, van Dongen EP, Noordzij PG. Intra-operative red blood cell transfusion and mortality after cardiac surgery. BMC Anesthesiol. 2019; 19(1):65.
32. Görlinger K, Maegele M, Lier H, Spahn DR. Effect of viscoelastic testing on mortality in bleeding patients with severe trauma: A meta-analysis. Paper presented at: The Anesthesiology Annual Meeting. 2024 Oct 19; Philadelphia, USA.
33. Görlinger K, Maegel M, Lier H, Karkouti K. Effect of viscoelastic testing on mortality in cardiovascular surgery, lung transplant and ECMO: a meta-analysis. Paper presented at: The Anesthesiology Annual Meeting. 2024 Oct 19; Philadelphia, USA.
34. Görlinger K, Gandhi A, Perez-Calatayud AA, Yassen KA, Bezinover D, Saner FH. Effect of viscoelastic testing on mortality in liver transplantation and cirrhotic patients undergoing invasive procedures: a meta-analysis. Paper presented at: NATA25 Annual Symposium. 2025 Apr 24-26; Munich, Germany.
35. Ranucci M, Aloisio T, Di Dedda U, Anguissola M, Barbaria A, Baryshnikova E. Fibrinogen and prothrombin complex concentrate: the importance of the temporal sequence-a post-hoc analysis of two randomized controlled trials. J Clin Med. 2024; 13(23):7137.
36. Grottke O, Mallaiah S, Karkouti K, Saner F, Haas T. Fibrinogen supplementation and its indications. Semin Thromb Hemost. 2020; 46(1):38-49.
37. Hinton JV, Xing Z, Fletcher C, Perry LA, Karamesinis A, Shi J, et al. Association of perioperative transfusion of fresh frozen plasma and outcomes after cardiac surgery. Acta Anaesthesiol Scand. 2024; 68(6):753-63.
38. Farmer SL, Towler SC, Leahy MF, Hofmann A. Drivers for change: Western Australia patient blood management program (WA PBMP), World Health Assembly (WHA) and advisory committee on blood safety and availability (ACBSA). Best Pract Res Clin Anaesthesiol. 2013; 27(1):43-58.
39. Pearse BL, Smith I, Faulke D, Wall D, Fraser JF, Ryan EG, et al. Protocol guided bleeding management improves cardiac surgery patient outcomes. Vox Sang. 2015; 109(3):267-79.
40. Newcomb AE, Dignan R, McElduff P, Pearse EJ, Bannon P. Bleeding after cardiac surgery is associated with an increase in the total cost of the hospital stay. Ann Thorac Surg. 2020; 109(4):1069-78.
41. Kietaibl S, Ahmed A, Afshari A, Albaladejo P, Aldecoa C, Barauskas G, et al. Management of severe peri-operative bleeding: guidelines from the European society of anaesthesiology and intensive care: second update 2022. Eur J Anaesthesiol. 2023; 40(4):226-304.
42. Munoz M, Stensballe J, Ducloy-Bouthors AS, Bonnet MP, De Robertis E, Fornet I, et al. Patient blood management in obstetrics: prevention and treatment of postpartum haemorrhage. A NATA consensus statement. Blood Transfus. 2019; 17(2):112-36.
43. Salenger R, Arora RC, Bracey A, D'Oria M, Engelman DT, Evans C, et al. Cardiac surgical bleeding, transfusion, and quality metrics: joint consensus statement by the enhanced recovery after surgery cardiac society and society for the advancement of patient blood management. Ann Thorac Surg. 2025; 119(2):280-95.
44. Mitra B, Jorgensen M, Reade MC, Keegan A, Holley A, Farmer S, et al. Patient blood management guideline for adults with critical bleeding. Med J Aust. 2024; 220(4):211-6.

45. Rossaint R, Afshari A, Bouillon B, Cerny V, Cimpoesu D, Curry N, et al. The European guideline on management of major bleeding and coagulopathy following trauma: Sixth edition. Crit Care. 2023; 27(1):80.
46. Escobar MF, Nassar AH, Theron G, Barnea ER, Nicholson W, Ramasauskaite D, et al. FIGO recommendations on the management of postpartum hemorrhage 2022. Int J Gynaecol Obstet. 2022; 157(Suppl 1):3-50.
47. Nanchal R, Subramanian R, Karvellas CJ, Hollenberg SM, Peppard WJ, Singbartl K, et al. Guidelines for the management of adult acute and acute-on-chronic liver failure in the ICU: cardiovascular, endocrine, hematologic, pulmonary, and renal considerations. Crit Care Med [Internet]. 2020; 48(3):e173-e91. Available from DOI: 10.1097/CCM.0000000000004192
48. Curry NS, Davenport R, Pavord S, Mallett SV, Kitchen D, Klein AA, et al. The use of viscoelastic haemostatic assays in the management of major bleeding: A British Society for haematology guideline. Br J Haematol. 2018; 182(6):789-806.
49. Ozawa S, Ozawa-Morriello J, Perelman S, Thorpe E, Rock R, Pearse BL. Improving patient blood management programs: an implementation science approach. Anesth Analg. 2023; 136(2):397-407.
50. Pearse BL, Keogh S, Rickard CM, Fung YL. Barriers and facilitators to implementing evidence based bleeding management in Australian cardiac surgery units: a qualitative interview study analysed with the theoretical domains framework and COM-B model. BMC Health Serv Res. [Internet]. 2021Jun; 21(550). Available from DOI: 10.1186/s12913-021-06269-8
51. Farmer SL, Ellis C, Hamdorf JM, Falconer D, Symons K, McNally C, et al. Patient blood management program implementation and assessment tool: measuring compliance with guidelines and World Health Organisation 2021 policy brief. Anesth Analg.[Internet]. 2025 Jan. Available from DOI: 10.1213/ANE.0000000000007364
52. Görlinger K, Perez-Ferrer A, Dirkmann D, Saner F, Maegele M, Calatayud AP, et al. The role of evidence-based algorithms for rotational thromboelastometry-guided bleeding management. Korean J Anesthesiol. 2019; 72(4):297-322.
53. Wahba A, Milojevic M, Boer C, De Somer F, Gudbjartsson T, van den Goor J, et al. 2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery. Eur J Cardiothorac Surg. 2020; 57(2):210-51.
54. Varshney A, Fathima Z, Hegde SG, Ollapally ATM. Association of anesthesiologist-surgeon dyad seniority on intraoperative outcomes. Anesth Analg. 2024; 139(6):1343-5.
55. Etherington C, Burns JK, Kitto S, Brehaut JC, Britton M, Singh S, et al. Barriers and enablers to effective interprofessional teamwork in the operating room: a qualitative study using the theoretical domains framework. PloS One. 2021; 16(4)
56. Telem DA, Dimick J, Skolarus TA. Dissecting surgeon behavior: Leveraging the theoretical domains framework to facilitate evidence-based surgical practice. Ann Surg. 2018; 267(3):432-4.
57. Cooper JB. Critical role of the surgeon-anesthesiologist relationship for patient safety. Anesthesiology. 2018; 129(3):402-5.
58. Pearse BL, Keogh S, Rickard CM, Faulke DJ, Smith I, Wall D, et al. Bleeding management practices of Australian cardiac surgeons, anesthesiologists and perfusionists: a cross-sectional national survey incorporating the theoretical domains framework (TDF) and COM-B model. J Multidiscip Healthc. 2020; 13:27-41.
59. Lenet T, Tropiano J, Skanes S, Ivankovic V, McIsaac D, Tinmouth A, et al. Understanding intraoperative transfusion decision-making variability: a qualitative study using the theoretical domains framework. Canadian Journal of Surgery. 2022; 65(S44).
60. Kazamer A, Ilinca R, Stanescu S, II, Lutescu DA, Greabu M, Miricescu D, et al. Perceptions of the conditions and barriers in implementing the patient blood management standard by anesthesiologists and surgeons. Healthcare (Basel). 2024; 12(7):760.
61. Driessnack M, Campbell M, Fornero K. Moving knowledge to action: aware, adopt, adapt (A3). The Journal for Nurse Practitioners. 2022; 18(5):503-5.
62. Pearse BL, Rickard CM, Keogh S, Lin Fung Y. A retrospective explanatory case study of the implementation of a bleeding management quality initiative, in an Australian cardiac surgery unit. Aust Crit Care. 2019; 32(2):92-9.
63. Moore JL, Mbalilaki JA, Graham ID. Knowledge translation in physical medicine and rehabilitation: a citation analysis of the knowledge-to-action literature. Arch Phys Med Rehabil. 2022; 103(7S):S256-S75.
64. Atkins L, Francis J, Islam R, O'Connor D, Patey A, Ivers N, et al. A guide to using the theoretical domains framework of behaviour change to investigate implementation problems. Implement Sci. 2017; 12(1):77.
65. Jain M CE SK, Malhotra S, Downs C. Introducing viscoelastic haemostatic assay-guided blood product transfusion into your hospital. Australasian Anaesthesia. 2017:77-93.
66. Bates J, Schrewe B, Ellaway RH, Teunissen PW, Watling C. Embracing standardisation and contextualisation in medical education. Med Educ. 2019; 53(1):15-24.
67. Li SA, Jeffs L, Barwick M, Stevens B. Organizational contextual features that influence the implementation of evidence-based practices across healthcare settings: a systematic integrative review. Syst Rev. 2018; 7(1):72.
68. Dryden-Palmer KD, Parshuram CS, Berta WB. Context, complexity and process in the implementation of evidence-based innovation: a realist informed review. BMC Health Serv Res. 2020; 20(1):81.
69. Currie G, White L. Inter-professional barriers and knowledge brokering in an organizational context: The case of healthcare. Organization Studies. 2012; 33(10):1333-61.
70. Ott M, Apramian T, Lingard L, Roth K, Cristancho S. The embodiment of practice thresholds: from standardization to stabilization in surgical education. Adv Health Sci Educ Theory Pract. 2021; 26(1):139-57.
71. Maxey-Jones C, Seelhammer TG, Arabia FA, Cho B, Cardonell B, Smith D, et al. TEG(R) 6s-guided algorithm for optimizing patient blood management in cardiovascular surgery: systematic literature review and expert opinion. J Cardiothorac Vasc Anesth. 2025; 39(5):1162-72.

72. Whitton TP, Healy WJ. Review of thromboelastography (TEG): medical and surgical applications. Ther Adv Pulm Crit Care Med. [Internet]. 2023; 18:29768675231208426. Available from DOI: 10.1177/29768675231208426
73. Bell SF, Taylor H, Pallmann P, Collins P, collaborators OBSC. Relationship between the dual platelet-inhibited ROTEM(R) sigma FIBTEM assay and Clauss fibrinogen during postpartum haemorrhage. Anaesthesia. 2025; 80(1):104-6.
74. de Vries JJ, Veen CS, Snoek CJ, Kruip M, de Maat MP. FIBTEM clot firmness parameters correlate well with the fibrinogen concentration measured by the Clauss assay in patients and healthy subjects. Scand J Clin Lab Invest. 2020; 80(7):600-5.
75. Calland JF, Guerlain S, Adams RB, Tribble CG, Foley E, Chekan EG. A systems approach to surgical safety. Surg Endosc. 2002; 16(6):1005-14.
76. Gawande AA, Zinner MJ, Studdert DM, Brennan TA. Analysis of errors reported by surgeons at three teaching hospitals. Surgery. 2003; 133(6):614-21.
77. Greenberg CC, Regenbogen SE, Studdert DM, Lipsitz SR, Rogers SO, Zinner MJ, et al. Patterns of communication breakdowns resulting in injury to surgical patients. J Am Coll Surg. 2007; 204(4):533-40.
78. Ostergaard D, Dieckmann P, Lippert A. Simulation and CRM. Best Pract Res Clin Anaesthesiol. 2011; 25(2):239-49.
79. Brown EK, Harder KA, Apostolidou I, Wahr JA, Shook DC, Farivar RS, et al. Identifying variability in mental models within and between disciplines caring for the cardiac surgical patient. Anesth Analg. 2017; 125(1):29-37.
80. Connelly NR, Adler AC, Vanderberg LE, Conlin F, Mitchell JD, Goldstein S, et al. Anesthesiology resident knowledge of transfusion medicine: results from the anesthesiology transfusion education study. Anesth Analg. 2024; 138(3):655-63.
81. Howard B, Diug B, Ilic D. Methods of teaching evidence-based practice: a systematic review. BMC Med Educ. 2022; 22(1):742.
82. Acharya Y, Raghavendra Rao MV, Arja S. Evidence-based medicine in pre-clinical years: a study of early introduction and usefulness. J Adv Med Educ Prof. 2017; 5(3):95-100.
83. Lehane E, Leahy-Warren P, O'Riordan C, Savage E, Drennan J, O'Tuathaigh C, et al. Evidence-based practice education for healthcare professions: an expert view. BMJ Evid Based Med. 2019; 24(3):103-8.
84. Min H, Morales DR, Orgill D, Smink DS, Yule S. Systematic review of coaching to enhance surgeons' operative performance. Surgery. 2015; 158(5):1168-91.
85. Stevens LM, Cooper JB, Raemer DB, Schneider RC, Frankel AS, Berry WR, et al. educational program in crisis management for cardiac surgery teams including high realism simulation. J Thorac Cardiovasc Surg. 2012; 144(1):17-24.
86. Wulf G, Chiviacowsky S, Schiller E, Avila LT. Frequent external-focus feedback enhances motor learning. Front Psychol. 2010; 1:190.
87. Salas E, Sims DE, Burke CS. Is there a “big five” in teamwork? Small Group Research. 2005; 36(5):555-99.
88. Levasseur RE. People skills: developing soft skills—a change management perspective. Interfaces. 2013; 43(6):566-71.
89. Wiegmann DA, Eggman AA, Elbardissi AW, Parker SH, Sundt TM, 3rd. Improving cardiac surgical care: a work systems approach. Appl Ergon. 2010; 41(5):701-12.
90. Lingard L. What we see and don't see when we look at 'competence': notes on a god term. Adv Health Sci Educ Theory Pract. 2009; 14(5):625-8.
91. Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW. Systems approaches to surgical quality and safety: from concept to measurement. Ann Surg. 2004; 239(4):475-82.
92. Gjeraa K, Spanager L, Konge L, Petersen RH, Ostergaard D. Non-technical skills in minimally invasive surgery teams: a systematic review. Surg Endosc. 2016; 30(12):5185-99.
93. Sawaya RD, Mrad S, Rajha E, Saleh R, Rice J. Simulation-based curriculum development: lessons learnt in global health education. BMC Med Educ. 2021; 21(1):33.
94. Elendu C, Amaechi DC, Okatta AU, Amaechi EC, Elendu TC, Ezeh CP, et al. The impact of simulation-based training in medical education: a review. Medicine (Baltimore) [Internet]. 2024 Jul; 103(27):e38813.Available from DOI: 10.1097/MD.0000000000038813
95. Schuler E, Mott S, Forbes PW, Schmid A, Atkinson C, DeGrazia M. Evaluation of an evidence-based practice mentorship programme in a paediatric quaternary care setting. J Res Nurs. 2021; 26(1-2):149-65.
96. Australian Commission on Safety and Quality in Health Care. Standard 7. Blood and blood products. Safety and Quality Improvement Guide [Internet]. 2012 Oct, Available from: https://www.safetyandquality.gov.au/sites/default/files/migrated/Standard7_Oct_2012_WEB.pdf
97. Reddy S. Exploration of funding models to support hybridisation of Australian primary health care organisations. J Prim Health Care. 2017; 9(3):208-11.
98. Sarkies M, Francis-Auton E, Long J, Roberts N, Westbrook J, Levesque JF, et al. Audit and feedback to reduce unwarranted clinical variation at scale: a realist study of implementation strategy mechanisms. Implement Sci. 2023; 18(1):71.
99. Hansen EE, Chiem JL, Righter-Foss K, Zha Y, Cockrell HC, Greenberg SLM, et al. Project SPRUCE: saving our planet by reducing carbon emissions, a pediatric anesthesia sustainability quality improvement initiative. Anesth Analg. 2023; 137(1):98-107.
100. Winearls J, Wullschleger M, Wake E, McQuilten Z, Reade M, Hurn C, et al. Fibrinogen early in severe trauma study (FEISTY): results from an Australian multicentre randomised controlled pilot trial. Crit Care Resusc. 2021; 23(1):32-46.