Getting "SMART" on Shock Treatment

An Evidence-Based Mnemonic Acronym for the Initial Management of Hemorrhage in Trauma

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ABSTRACT

Treating hemorrhagic shock is challenging, the pathology is complex, and time is critical. Treatment requires resources in mental bandwidth (i.e., focused attention), drugs and blood products, equipment, and personnel. Providers must focus on treatment options in order of priority while also maintaining a dynamic assessment of the patient's response to treatment and considering potential differential diagnoses. In this process, the cognitive load is substantial. To avoid errors of clinical reasoning and practical errors of commission, omission, or becoming fixated, it is necessary to use evidence-based treatment recommendations that are concise, in priority order, and easily recalled. This is particularly the case in the austere, remote, or tactical environment. A simple mnemonic acronym, SMART, is presented in this article. It is a clinical heuristic that can be used as an aide-mémoire during the initial phases of resuscitation of the trauma patient with hemorrhagic shock: Start the clock and Stop the bleeding; Maintain perfusion; Administer antifibrinolytics; Retain heat; Titrate blood products and calcium; Think of alternative causes of shock.

KEYWORDS: *hemorrhage; shock; treatment; mnemonic; acronym; heuristic*

Introduction

Trauma remains a significant cause of death worldwide in all societies.[1] Injury to the central nervous system (including traumatic brain injury) is the overall leading cause of death from trauma, but hemorrhage is estimated to be responsible for 40% to 50% of deaths resulting from traumatic injury.[2] One comprehensive review of military battlefield deaths found that hemorrhage is the leading cause of death for patients deemed to have succumbed to potentially survivable injuries, with most of these occurring in the prehospital environment.[3] Eastridge et al.[3] concluded that 24.3% of the deaths occurring before patients reach a medical treatment facility were potentially survivable, but the researchers highlighted that 90.9% of these were due to hemorrhage. Furthermore, 67.3% of these deaths due to hemorrhage were attributed to truncal hemorrhage. Hence, in remote settings, when surgical management of truncal hemorrhage is rarely available, it is vital that prehospital care providers are trained and equipped to manage catastrophic hemorrhage and, when necessary, to maintain critical perfusion with appropriate resuscitation fluids. The systematic introduction of training programs to address the challenges of reducing preventable death due to traumatic injuries is highly effective if the appropriate training, resources, and commitment from the command hierarchy are implemented.[4]

Cognitive Strategies to Optimize Decision-Making in High-Stress Environments

Care of patients with severe traumatic injuries, particularly the initiation of remote damage control resuscitation in hostile or austere environments, represents one of the most stressful challenges in clinical medicine.[5] Responsibility for the initial resuscitation of critically injured patients often falls to their medically trained comrades or relatively inexperienced frontline medical personnel. The risk of cognitive error is increased in such settings and so an understanding of why mistakes occur and how to avoid them is important in structuring training of personnel and the provision of appropriate decision-support tools.[6,7] Similarly, providers must be aware of the risks of cognitive bias and strategies to minimize the risk of this occurring.[8,9] In such high-stress, time-critical environments, the use of checklists is recommended and widely acknowledged to reduce stress and improve performance.[10]

Although the use of written checklists may be impractical in such uncompromising environments, there is evidence that other cognitive aids, including mnemonics, can improve the retention and recall of key information in medical settings.[11–13] Heuristic decision-making with the aid of simple mnemonics has the potential to improve accuracy and speed of decision-making in complex, high-stress settings.[14] Although mnemonic acronyms such as C-ABCDE (catastrophic hemorrhage, airway with spinal protection, breathing, circulation, disability [neurological] and exposure and environment) or MARCH (massive bleeding, airway, respiration, circulation, head and hypothermia) are already widely used to guide the overall order of resuscitation priorities for trauma patients, these mnemonics give no triggers to recall the detail of what treatments are required to manage life-threatening hemorrhage—the commonest cause of potentially preventable death due to trauma. There is a risk that medical providers in highly stressed environments may be unable to recall which time-critical interventions need to be delivered to remedy "circulation" problems as they are identified in the initial assessment and treatment of the shocked trauma patient.

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Therefore, we propose use of an additional mnemonic acronym, SMART, to assist with the recall of key strategies in the resuscitation of casualties with hemorrhage in trauma. Providers should be taught to initiate the use of this mnemonic acronym when caring for a patient with visible catastrophic hemorrhage or a patient with traumatic injuries who, on structured assessment (e.g., by using the MARCH or C-ABCDE approach), is suspected of being at risk of life-threatening hemorrhage.

Management of Hemorrhagic Shock in Trauma Patients

The pathogenesis of the coagulopathy that occurs in patients after traumatic injury is complex but has been increasingly well described in recent years. Brohi et al.[15] in 2003 observed that there is a coagulopathy seen in trauma patients that cannot be attributed solely to the adverse effects of fluid replacement given during resuscitation. The authors suggested the traumatic process itself results in the release of factors that contribute to this coagulopathy. Hess et al.[16] in 2008 described some of the complex mechanisms that contribute to this coagulopathy. After traumatic injury, tissue factors are released that initiate both coagulation and fibrinolysis. The hypoperfusion that results from untreated severe hemorrhage then causes acidosis, which, in turn, leads to additional imbalance of normal clotting mechanisms. This coagulopathy contributes to additional bleeding and, hence, worsening tissue perfusion. Hypoperfusion, in turn, causes a reduction in oxygen delivery, leading to tissue ischemia and accumulation of lactate. This has been described as causing an "oxygen debt."[17] Although such a debt can lead to irreversible organ failure, it has also been suggested that it causes failure of endothelial function which, combined with acute traumatic coagulopathy, may constitute "blood failure."[18] The early use of blood products to restore blood function toward normal is a key strategy to minimize the ischemic insult to all organs.

Injudicious resuscitation attempts with room temperature crystalloid fluids can then lead to hemodilution and hypothermia, both of which can cause further disruption of coagulation. Early treatment, therefore, is directed at stopping bleeding, maintaining tissue perfusion with the optimum resuscitation fluids available, countering hyperfibrinolysis, preventing hypothermia, and titrating blood products to further maintain perfusion and replace clotting components. Emerging evidence from the Afghanistan conflict emphasizes the survival benefit of blood-product administration as soon as possible after injury.[19] Prehospital administration of plasma reduces 30-day mortality when used by civilian air medical transport teams.[20] These actions can be summarized as follows:

- Start the clock and stop the bleeding
- Maintain perfusion
- Administer antifibrinolytics
- Retain heat
- Titrate blood products and calcium; think of alternative causes of shock

A vital strategy in the resuscitation of shocked patients with traumatic injuries in any environment, but particularly in austere and resource-poor healthcare settings, is to monitor the patient's response to resuscitation and always consider that there may be alterative causes of shock. Shock due to tension pneumothorax may develop rapidly in severely injured patients, or they may experience neurogenic shock, both of which can be confused with hemorrhagic shock. Later, during prolonged field care, other causes of shock may have to be considered, including sepsis and venous thromboembolism.

With greater understanding of the underlying processes has come clearer evidence for treatment strategies that address these problems. In 2016, Rossaint et al.[21] published the updated European guideline for the management of major bleeding and coagulopathy after trauma. Recent revision of the Tactical Combat Casualty Care guidelines also included specific evidence-based recommendations about the hierarchy of early blood-product administration to patients with hemorrhagic shock.[22] The 2016 European guideline includes 39 evidence-based recommendations that cover all aspects of care, from initial resuscitation through quality management strategies. Key recommendations include that evidence-based treatment algorithms are implemented and that checklists are used to guide patient care.

SMART Mnemonic Acronym: Recommendations

S – Start the clock

- Minimize the time from point of injury to surgical control of bleeding.
- Minimize time to resuscitation with blood products.

Life-threatening bleeding must be stopped as quickly as possible by whatever means, including surgical intervention. Death of trauma patients who have suffered significant torso injury occurs very rapidly, and so the time from injury to hemorrhage control must be minimized.[23] Shackelford et al.[19] have also highlighted the beneficial impact of early blood product administration on survival.

– Stop the bleeding

- Tourniquet use
- Immediate bleeding control procedure

The reintroduction of effective field limb tourniquets has led to a demonstrable improvement in survival for patients with life-threatening hemorrhage from the extremities. For the management of junctional hemorrhage, other techniques and devices have become available, and so the use of these devices is emphasized in this mnemonic.

M – Maintain perfusion

- Fluid therapy in the hypotensive bleeding patient
- Target systolic blood pressure of 100mmHg

If there are any delays in time to hemorrhage control, then organ perfusion must be maintained with appropriate products. Failure to maintain perfusion causes critical reduction in oxygen delivery to vital organs, and so care providers must instigate fluid therapy with the optimum available fluid to maintain critical perfusion. Although a strategy of hypotensive resuscitation may be appropriate for a short duration in patients without evidence of traumatic brain injury, prolonged or profound hypotension below 100 mmHg should be avoided.[24] If blood pressure monitoring is unavailable in particularly austere environments, then providers should consider loss of radial pulses as a trigger to initiate fluid therapy but should monitor for return of pulses to avoid excessive fluid administration.

A – Administer tranexamic acid

- Tranexamic acid for a patient who is bleeding or at risk of significant hemorrhage

The CRASH 2 trial demonstrated a clear survival benefit for patients with traumatic injuries at risk of significant hemorrhage when tranexamic acid was administered within 3 hours

of injury. Therefore, tranexamic acid should be given as soon as possible.[25] This effect was also demonstrated in a military setting in the Military Application of Tranexamic Acid in Trauma Emergency Resuscitation study.[26]

R – Retain heat

- Achieve and maintain normothermia.

The detrimental effects of hypothermia and hyperthermia on coagulation and, hence, death have been clearly demonstrated and so providers must take measures to retain heat and maintain normothermia.[27]

T – Titrate blood products and calcium

- Fresh whole blood (FWB) improves survival compared with administration of 1:1 plasma and red blood cells (RBCs)
- If FWB not available, then plasma, RBCs, and platelets should be administered in a 1:1:1 ratio.
- If platelets not available, then plasma and RBCs should be administered in a 1:1 ratio.
- If not available, then use reconstituted dried plasma, liquid plasma, or thawed plasma alone or RBCs alone.
- Give calcium, especially when giving citrated blood products.
- Administer fibrinogen if there is functional deficit or plasma fibrinogen level is below 1.5–2.0g/L.[21]

Appropriate blood products should be administered as early as possible for patients with traumatic injuries who have evidence of organ hypoperfusion. In resource-poor settings, this may be based purely on loss of radial pulse, but when blood pressure monitoring is available, then a shock index (heart rate/systolic blood pressure) greater than 1 predicts the need for massive transfusion.[28] Schreiber et al.[29] identified variables for patients arriving at combat support hospitals in Iraq that predicted the need for massive transfusion, but these investigations are rarely available in the prehospital environment. Another assessment tool that predicts the need for massive transfusion has been adopted by the US Army 75th Ranger Regiment for the prehospital administration of whole blood.[30] This suggests that the critical values for initiating transfusion are a systolic blood pressure between 80 and 100mmHg or lower, lactate level of 5mmol/L or higher, heart rate greater than 100 bpm, and tissue oxygen saturation not more than 70%. The Norwegian Naval Special Operation Commando remote damage control resuscitation protocol for prehospital whole-blood transfusion also identifies triggers to initiate transfusion that include mechanism of injury together with any one of a series of similar parameters (e.g., weak or absent radial pulse, heart rate >120 bpm, altered mentation without head injury, systolic blood pressure <90mmHg, lactate level >5mmol/L, or tissue oxygen saturation <65%).[31] The Committee on Tactical Combat Casualty Care has published an evidence-based recommendation of which blood products, in order of preference, should be used for the management of life-threatening hemorrhage, with FWB being the preferred resuscitation fluid.[22]

– Think of alternative causes of shock

- Obstructive shock: Tension pneumothorax, especially when patient is receiving positive-pressure ventilatory support, and cardiac tamponade, especially when there is penetrating trauma to the thorax
- Distributive shock: Mechanism for spinal injury or reaction to medications given

Life-threatening hemorrhage is the leading cause of preventable death in battlefield trauma, but it must not be forgotten that there are other, far less commonly encountered causes of shock that may occur due to traumatic injuries. Therefore, providers must consider pausing at the end of the initial interventions to manage hemorrhagic shock to consider whether there may be other causes for the shock state, particularly if the patient has failed to respond to any of the aforementioned interventions. Cognitive psychology suggests that such use of slower, System 2 thinking further reduces the risk of error in such settings.[32]

FIGURE 1 *Key actions indicated by the SMART mnemonic for treatment of hemorrhagic shock.*

S – Start the clock and Stop the bleeding.
M – Maintain perfusion.
A – Administer antifibrinolytics.
R – Retain heat.
T – Titrate blood products and calcium.
Think alternative causes of shock.

Conclusion

In this article, an evidence-based mnemonic acronym has been presented that is designed to aid retention and recall of the key treatment strategies in the initial resuscitation of patients with hemorrhage in trauma. Evidence suggests the implementation of such cognitive aids may enhance recall of key information and reduce stress when medically trained personnel are required to treat time-critical injuries in hostile or austere environments.

Author Contributions

PT conceived the mnemonic. AH made critical suggestions and wrote the first draft of the manuscript. PT and AH reviewed the relevant literature and read, revised, and approved the final manuscript.

Disclosures

The authors have indicated that they have no financial relationships relevant to this article to disclose.

References

1. **Murray CJ, Vos T, Lozano R, et al.** Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2197–1223.
2. **Sauaia A, Moore FA, Moore EE, et al.** Epidemiology of trauma deaths: a reassessment. *J Trauma*. 1995;38(2):185–193.
3. **Eastridge BJ, Mabry RL, Seguin P, et al.** Death on the battlefield (2001-2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S431–437.
4. **Kotwal RS, Montgomery HR, Kotwal BM, et al.** Eliminating preventable death on the battlefield. *Arch Surg*. 2011;146(12):1350–1358.
5. **Jenkins DH, Rappold JF, Badloe JF, et al.** Trauma hemostasis and oxygenation research position paper on remote damage control resuscitation: definitions, current practice, and knowledge gaps. *Shock*. 2014;41(Suppl 1):3–12.
6. **Scott IA.** Errors in clinical reasoning: causes and remedial strategies. *BMJ*. 2009;338:b1860.
7. **Fioratou E, Flin R, Glavin R.** No simple fix for fixation errors: cognitive processes and their clinical applications. *Anaesthesia*. 2010;65(1):61–69.
8. **Croskerry P.** The importance of cognitive errors in diagnosis and strategies to minimize them. *Acad Med*. 2003;78(8):775–780.
9. **O'Sullivan ED, Schofield SJ.** Cognitive bias in clinical medicine. *J R Coll Physicians Edinb*. 2018;48(3):225–232.
10. **Gawande A.** *The Checklist Manifesto : How to Get Things Right*. 1st ed. New York, NY: Metropolitan Books; 2010, 209 p.

11. **Dyson E, Voisey S, Hughes S, et al.** Educational psychology in medical learning: a randomised controlled trial of two aide memoires for the recall of causes of electromechanical dissociation. *Emerg Med J*. 2004;21(4):457–460.
12. **Gravel J, Roy M, Carriere B.** 44-55-66-PM, a mnemonic that improves retention of the Ottawa Ankle and Foot Rules: a randomized controlled trial. *Acad Emerg Med*. 2010;17(8):859–864.
13. **Long E, Fitzpatrick P, Cincotta DR, et al.** A randomised controlled trial of cognitive aids for emergency airway equipment preparation in a paediatric emergency department. *Scand J Trauma Resusc Emerg Med*. 2016;24:8.
14. **Marewski JN, Gigerenzer G.** Heuristic decision making in medicine. *Dialogues Clin Neurosci*. 2012;14(1):77–89.
15. **Brohi K, Singh J, Heron M, et al.** Acute traumatic coagulopathy. *J Trauma*. 2003;54(6):1127–1130.
16. **Hess JR, Brohi K, Dutton RP, et al.** The coagulopathy of trauma: a review of mechanisms. *J Trauma*. 2008;65(4):748–754.
17. **Bjerkvig CK, Strandenes G, Eliassen HS, et al.** "Blood failure" time to view blood as an organ: how oxygen debt contributes to blood failure and its implications for remote damage control resuscitation. *Transfusion (Paris)*. 2016;56(Suppl 2):S182–189.
18. **White NJ, Ward KR, Pati S, et al.** Hemorrhagic blood failure: oxygen debt, coagulopathy, and endothelial damage. *J Trauma Acute Care Surg*. 2017;82(6S Suppl 1):S41–S49.
19. **Shackelford SA, Del Junco DJ, Powell-Dunford N, et al.** Association of prehospital blood product transfusion during medical evacuation of combat casualties in Afghanistan with acute and 30-day survival. *JAMA*. 2017;318(16):1581–1591.
20. **Sperry JL, Guyette FX, Brown JB, et al.** Prehospital plasma during air medical transport in trauma patients at risk for hemorrhagic shock. *N Engl J Med*. 2018;379(4):315–326.
21. **Rossaint R, Bouillon B, Cerny V, et al.** The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition. *Crit Care*. 2016;20:100.
22. **Committee on Tactical Combat Casualty Care.** *Tactical Combat Casualty Care Guidelines for Medical Personnel*. http://www.cotccc.com/.
23. **Alarhayem AQ, Myers JG, Dent D, et al.** Time is the enemy: mortality in trauma patients with hemorrhage from torso injury occurs long before the "golden hour." *Am J Surg*. 2016;212(6):1101–1105.
24. **Woolley T, Thompson P, Kirkman E, et al.** Trauma Hemostasis and Oxygenation Research Network position paper on the role of hypotensive resuscitation as part of remote damage control resuscitation. *J Trauma Acute Care Surg*. 2018;84(6S Suppl 1):S3–S13.
25. **Shakur H, Roberts I, Bautista R, et al.** Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised, placebo-controlled trial. *Lancet*. 2010;376(9734):23–32.
26. **Morrison JJ, Dubose JJ, Rasmussen TE, et al.** Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) Study. *Arch Surg*. 2012;147(2):113–119.
27. **Wade CE, Salinas J, Eastridge BJ, et al.** Admission hypo- or hyperthermia and survival after trauma in civilian and military environments. *Int J Emerg Med*. 2011;4(1):35.
28. **Schroll R, Swift D, Tatum D, et al.** Accuracy of shock index versus ABC score to predict need for massive transfusion in trauma patients. *Injury*. 2018;49(1):15–19.
29. **Schreiber MA, Perkins J, Kiraly L, et al.** Early predictors of massive transfusion in combat casualties. *J Am Coll Surg*. 2007;205(4):541–545.
30. **Fisher AD, Miles EA, Cap AP, et al.** Tactical damage control resuscitation. *Mil Med*. 2015;180(8):869–875.
31. **Strandenes G, De Pasquale M, Cap AP, et al.** Emergency whole-blood use in the field: a simplified protocol for collection and transfusion. *Shock*. 2014;41(Suppl 1):76–83.
32. **Kahneman D.** *Thinking, Fast and Slow.* New York, NY: Farrar, Straus and Giroux; 2013.