

# Prioritizing Circulation to Improve Outcomes for Patients with Exsanguinating Injury: A Literature Review and Techniques to Help Clinicians Achieve Bleeding Control

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Trauma care has followed the airway, breathing, circulation (ABC) approach developed by the Advanced Trauma Life Support course. This methodology focuses on treating the airway first, on many occasions resulting in intubation before addressing breathing and circulation issues during the primary survey. This is also referred to as the “first resuscitation cycle” which is basically the initial phase of medical intervention and care provided to a patient who is in a critical or life-threatening condition. This cycle encompasses the immediate actions taken to stabilize the patient’s vital functions and address any emergent medical issues to prevent further deterioration and potentially save their life.<sup>1,2</sup>

In essence, the ABC approach underscores the sequential importance of addressing the airway, breathing, and circulation in the initial evaluation of trauma patients. Although the methodology traditionally places a strong emphasis on securing the airway first, it is important to note that medical practices and protocols continue to evolve based on ongoing research and advancements in trauma care. As a result, variations and adaptations of the ABC approach might emerge over time to better cater to the specific needs of patients and improve overall outcomes in trauma management.

## CME questions for this article available at <http://jacscme.facs.org>

**Disclosure Information:** Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose. Ronald J Weigel, CME Editor, has nothing to disclose.

**Disclosures outside the scope of this work:** Dr Brenner served as a Prytime Medical Inc Clinical Advisory Board Member and has been a chapter coauthor for UpToDate Inc.

**Support:** Dr Zakrisson receives federal funding for research from the NIH, DOJ, and the Robert Wood Johnson Foundation.

Received August 21, 2023; Revised September 13, 2023; Accepted September 13, 2023.

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In busy urban trauma centers, these steps are usually performed simultaneously with a large multispecialty team. In rural and resource-limited environments, these steps are often performed sequentially by a single physician. Although promulgated widely, and at this point the standard of care for patients with traumatic injury, the ABC approach has been supported primarily by expert consensus rather than scientific evidence.

In cases of nontraumatic cardiac arrest, there has been a shift in protocols during the past decade to prioritize perfusion through early chest compressions instead of securing the airway first. This change was based on evidence that the circulation-airway-breathing (CAB) approach would shorten time to restoring perfusion, leading to better outcomes. Although the pathophysiology of nontraumatic cardiac arrest differs greatly from that of hypovolemic shock, where one involves a nonfunctioning pump and the other revolves around volume, a common thread emerges: prioritizing perfusion can significantly impact patient outcomes. Notably, in instances of nontraumatic cardiac arrest, a notable shift in protocols has occurred in the past decade, favoring the initiation of early

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**Abbreviations and Acronyms**

ABC	=	airway, breathing, circulation
ACS	=	American College of Surgeons
CAB	=	circulation-airway-breathing

chest compressions over immediate airway management. This shift is grounded in evidence supporting the CAB approach, which aims to expedite the restoration of perfusion and ultimately lead to improved results. Remarkably, this practice has now become the standard CPR recommendation by the American Heart Association.<sup>3-7</sup>

From a physiologic standpoint, it makes sense to prioritize circulation in patients who suffered injury leading to exsanguinating hemorrhage, because it is the primary cause of their instability. The approach of prioritizing circulation before intubation might benefit patients who are hypotensive, in hypovolemic shock class 4. Timely resuscitation with blood products, in conjunction with the CAB approach, holds promise for improving trauma patient outcomes for patients who present with exsanguinating hemorrhage.

In intubating exsanguinating patients, the loss of vasoconstriction and potential vasodilation, along with obstructed airway gasping and positive pressure ventilation, can lead to cardiovascular arrest, worsening perfusion.<sup>4,5</sup> Efforts to enhance severe bleeding injury management focus on euvolemic, hemostatic resuscitation with blood products, reducing crystalloid fluid use, and minimizing bleeding control time. The American College of Surgeons (ACS) Stop the Bleed program globally trains individuals to promptly address compressible exsanguinating bleeding injury through direct pressure, wound packing, and tourniquet application, emphasizing circulation and euvolemic resuscitation.<sup>5-9</sup>

Challenges persist for injuries with noncompressible bleeding, necessitating strategies like early resuscitation with blood products, REBOA, and resuscitative thoracotomy to delay cardiovascular arrest in patients with severe hypovolemia and signs of life.<sup>3</sup> Time efficiency is crucial in achieving the ACS Committee on Trauma's goal of zero preventable trauma deaths, prompting the transition from the "golden hour" to a "platinum 10 minutes" for hemorrhage control in response to the rising incidence of high-velocity weapon-related injury.<sup>3-7</sup> Prioritizing circulation over airway in patients with severe bleeding is pivotal for improving outcomes.

Our belief in prioritizing circulation in patients with exsanguinating hemorrhage stems from our collective clinical experience, which includes the invaluable insights of our senior authors with decades of expertise in caring for injured patients. We felt compelled to delve deeper into this concept by conducting a comprehensive review of the available literature. Our approach was intentionally inclusive, encompassing clinical studies, foundational scientific research, basic science research, and input from an esteemed emergency medicine expert specializing in resuscitation. Our goal was to assemble a diverse and well-rounded group of healthcare professionals, each possessing extensive experience, united by a shared commitment to improving the care provided to critically injured patients. Importantly, we aimed to bridge the gap between high-income healthcare environments and regions with limited resources, recognizing the universal importance of enhancing hemorrhage management, even in rural and lower-income settings.

It is essential to challenge the status quo and embrace paradigm shifts based on new evidence to advance scientific knowledge and ultimately improve patient outcomes. Creating awareness about these shifts and implementing them in trauma care practices is the first step in this process and the focus of this review.

**Literature review supporting prioritizing circulation in injured patients**

Recent research has prompted a comparison between the conventional ABC resuscitation approach and the newer CAB model. Despite the historical use of the ABC method, there is a growing consideration, particularly in intricate trauma cases involving multiple injuries and hemorrhagic shock, that prioritizing initial intubation before addressing circulation can lead to unfavorable outcomes. This is thought to be due to the physiologic response of vasodilation triggered by rapid sequence intubation in patients who are already experiencing reduced blood volume, resulting in worsened hypotension and subsequent inadequate organ perfusion.<sup>4,8-10</sup>

The original guiding principles for ABC resuscitation were put forth without a body of literature showing conclusive evidence of improved outcomes, and specifically without data from high-quality clinical trials. The application of the ABC model in all situations in which patients require resuscitation has not been studied.<sup>9</sup> The ABC model has been taught widely through formal and informal training programs for many decades and is often accepted without question by physicians performing the initial resuscitation of trauma patients, most of whom are not subspecialty-trained trauma surgeons.<sup>2</sup>

Evidence suggests that early intubation, particularly in patients with traumatic brain injury, does not improve outcomes and can even worsen morbidity and mortality.<sup>11-16</sup> In these studies, the authors showed that intubation in the field led to longer ventilator requirements (CAB 10.4 days vs ABC 14.7 days), hospital length of stay (CAB 16.7 vs ABC 20.2 days), ICU duration (CAB 11.7 days vs ABC 15.2 days), and almost 2 times the mortality rate (CAB 12.4% vs ABC 23%).<sup>12</sup> Other studies have shown an association between early field intubation and increased rate of in-hospital pneumonia compared with intubation in the hospital.<sup>15</sup> There are also high-level meta-analyses showing that postintubation hypotension is a significant problem and can worsen mortality (CAB 19.6% vs ABC 33.2%,  $p < 0.001$ ).<sup>5</sup> Although there have been suggestions in the literature that the traditional ABC protocol is not highly effective, the focus has now shifted toward evaluating whether CAB is advantageous in the resuscitation of patients.

A review of the literature shows benefit from CAB compared with ABC regarding early intervention. In a randomized, simulated study looking at 108 teams, comparing ABC vs CAB, Marsch and colleagues<sup>16</sup> documented that the time to first resuscitation cycle was shorter in the CAB cohort (CAB 48 + 10 seconds vs ABC 63 + 17 seconds,  $p < 0.0001$ ) because responders were less focused on the airway. Similarly, in another simulated study with 340 volunteers, focusing on CAB compared with ABC, Lubrano and colleagues<sup>17</sup> reported a quicker response time to intervention such as chest compressions (CAB 19.27 + 2.64 seconds vs ABC 43.40 + 5.036 seconds,  $p < 0.05$ ) when initial resuscitation efforts were redirected from the airway to circulation. Therefore, one can realistically hypothesize that in trauma patients this approach would equate to early compressions, or earlier resuscitation with blood, instead of diverting the limited resources available to establishment of an airway.

When looking specifically at the trauma literature, there is emerging evidence documenting that CAB may be more effective in trauma patients.<sup>18</sup> In a study of pediatric patients, Sokol and colleagues<sup>18</sup> evaluated 766 pediatric

trauma patients who presented between 2004 and 2012 to Camp Bastion in Afghanistan. Their analysis showed that 20% of the patients who presented required intervention, most commonly circulatory-related (51%), then airway-related (40%), then breathing-related (8.7%). Their review showed that patients with a traumatic brain injury and an intervention related to airway first had a higher unadjusted mortality rate (56% vs 20%,  $p < 0.01$ ) and had a mortality odds ratio of 5.9 ( $p = 0.001$ ) when adjusted for in a multivariate analysis. Overall, their results argue that circulation should be the primary focus early in assessment as opposed to airway.

In the adult population, there have been a series of retrospective studies examining the role of CAB vs ABC as well as several meta-analyses and summary statements examining these results.<sup>19</sup> In 2018, Ferrada and colleagues<sup>6</sup> published a landmark American Association for the Surgery of Trauma multicenter trial that was a retrospective analysis of 440 patients from 2014 to 2016. The initial report demonstrated that 55.7% of centers involved were already practicing CAB, but 44.3% continued to practice intubation first (traditional ABC). When controlling for demographics, there was no difference in mortality rate between the 2 groups (CAB 47% vs ABC 50%), and the only predictors of mortality were initial systolic blood pressure and Glasgow Coma Score. A recent review of the existing literature in trauma patients by Breeding and colleagues<sup>19</sup> found that hypotensive trauma patients, especially those with active hemorrhage, may benefit more from a CAB approach to resuscitation, because early intubation may increase mortality secondary to postintubation hypotension.

Overall, there is a growing body of evidence and discussion suggesting that a circulation-first approach is justified when caring for trauma patients, particularly those in hemorrhagic shock.<sup>20,21</sup> Patients in hemorrhagic shock are particularly prone to the circulatory collapse associated with early intubation and require adequate resuscitation before airway control. Larger prospective clinical studies in both military and civilian populations are essential to definitively establish the preferred method of resuscitation. This will improve outcomes from trauma, which remains the leading cause of mortality in young adults and children in the US and around the world.

### Science behind prioritizing circulation in the patient with exsanguinating injury

Animal models have been instrumental in determining the physiology surrounding prehospital intervention for trauma patients and providing evidence for practice-changing clinical studies. Using a swine model of hemorrhage,

Bickell and colleagues<sup>22</sup> demonstrated that intravenous fluids in penetrating trauma diluted coagulation factors and exacerbated uncontrolled hemorrhage. These data led to a randomized control trial that definitively showed that “permissive hypotension” in the prehospital setting led to improved outcomes for trauma patients.<sup>23</sup> Similarly, laboratory studies have shown that a circulation first strategy is better in hemorrhagic shock models.<sup>24-28</sup> An animal model of hemorrhagic shock in rats showed that intubation does not provide a survival advantage. Positive pressure ventilation resulted in worsening perfusion of end-organs, resulting in higher lactate levels and a worse base deficit.<sup>27</sup>

Translational studies using trauma-relevant, large-animal models have confirmed findings that suggest that a circulation-first strategy may be beneficial in trauma patients.<sup>26,27</sup> In a severe hemorrhagic shock model using swine, endotracheal intubation and positive pressure ventilation were found to decrease venous return and result in decreased cardiac output and lower blood pressure.<sup>26,27</sup> Endotracheal intubation also contributed to hypothermia because bypass of the upper airways results in delivery of less humidified air.<sup>7</sup> Animals that received intubation or positive pressure via bag-valve-mask ventilation had worse perfusion of vital organs as measured by renal function. Interestingly, animals that received passive oxygen administration simply by facemask demonstrated better hemodynamic values, introducing the concept of “permissive hypoventilation.”<sup>27</sup> Other animal studies have shown that passive delivery of supplemental oxygen via facemask without administering positive pressure ventilation results in equally effective oxygen delivery compared with intubation and positive pressure ventilation. Taken together, animal studies have shown that an airway-first approach in hemorrhagic shock may worsen patient outcomes by decreasing venous return that results in less perfusion of vital organs.

### **Methods to maintain oxygenation while implementing a circulation-airway-breathing approach in the emergency department**

Managing trauma patients in hemorrhagic shock is physiologically challenging due to factors like hypovolemia, metabolic acidosis, and often hypoxia. During the initial evaluation and resuscitation phase, it is essential to address the airway while simultaneously attending to these critical physiologic issues. Basic airway maneuvers, including opening the airway, providing high-flow oxygen through a facemask or bag-valve-mask, and inserting a naso- or oropharyngeal airway if necessary, can support oxygenation and ventilation. These measures buy time for the trauma team to address exsanguinating hemorrhage sources and provide volume resuscitation. In cases requiring operative

intervention, these basic measures can continue, and intubation can be performed just before operation.

However, some situations demand urgent invasive airway management. These include patients who are actively vomiting, highly agitated, have significant maxillofacial, neck, or airway burn trauma, or suffer from a significant traumatic brain injury. Proceeding with rapid sequence intubation in such cases requires careful consideration. The Advanced Trauma Life Support guidelines have shifted from rapid sequence intubation to drug-assisted intubation to encompass all intubations requiring medication administration.

Rapid sequence intubation medications used for anesthesia induction pose inherent risks, particularly in hemorrhagic shock, where they can lead to hypotension and increase the risk of cardiac arrest.<sup>28</sup> Paralytic agents, often necessary for optimal intubation conditions, render the patient apneic, causing them to lose respiratory compensation for severe metabolic acidosis until ventilation resumes, worsening acidosis and risking cardiac arrest. Multiple intubation attempts elevate the risk of hypoxemia and ultimately cardiac arrest. Additionally, positive pressure ventilation further compromises venous return and cardiac output in these patients.<sup>29-31</sup>

To standardize the approach to intubation in ongoing physiologic threats, drug selection should prioritize medications like ketamine and etomidate, which minimally affect hemodynamics. Even in shock states, these drugs can lead to hypotension, necessitating reduced dosages (eg ketamine at 0.5 mg/kg, etomidate at 0.15 mg/kg) in hemorrhagic shock cases. Postintubation sedation can be achieved with bolus doses of fentanyl or additional ketamine to balance sedation needs with hemodynamic stability. Consideration should also be given to using both volume resuscitation and low-dose vasopressor medications to support circulation during the peri-intubation period.

During the apneic period induced by paralytic agents, the intubating clinician can continue bag-valve-mask ventilation to match preintubation minute ventilation, as demonstrated in a study by Casey and colleagues<sup>30</sup> involving 401 critically ill patients. However, care should be taken not to be overly aggressive with bag-valve-mask breaths postintubation. Preintubation minute ventilation should be matched to ensure proper compensation for metabolic acidosis, with consideration of an early transition to a mechanical ventilator to ensure consistent tidal volume delivery.

### **Role of euvolemic resuscitation in prioritizing circulation for the resuscitation in patients with active hemorrhage**

Given that exsanguinating hemorrhage is a primary source of preventable early death among trauma victims,<sup>31-34</sup> the

CAB approach is logically beneficial, because it addresses the more lethal problem first. In fact, timely resuscitation, preferably with whole blood as the first product, has been shown to significantly improve the outcomes of trauma patients with exsanguinating injury.<sup>35</sup> Brill and colleagues<sup>36</sup> showed that, compared with using blood component therapy in patients experiencing hemorrhagic shock, whole-blood transfusion improved 30-day survival by 60% and reduced the need for 24-hour blood products by 7%. Using whole blood rather than component therapy, or crystalloid, enables euvolemic resuscitation—a state where the blood being lost is replaced in a “like for like” scenario, preventing the hemodilution and coagulopathy that plagued early efforts at resuscitation of bleeding patients. Additionally, the Holcomb and colleagues<sup>37</sup> showed that among patients with severe trauma and major bleeding, early administration of plasma, platelets, and red blood cells in a 1:1:1 ratio compared with a 1:1:2 ratio did not result in significant differences in mortality at 24 hours or at 30 days. In conjunction with a CAB approach, a balanced euvolemic resuscitation effort is likely the best strategy to gain optimal outcomes for the trauma patient.

### **The Stop the Bleed perspective on circulation-airway-breathing**

Rapid bleeding cessation is paramount to prevent hypovolemic shock. In response to events like multiple casualty shootings, a collaborative effort led by trauma surgeons in Hartford, CT, the ACS, and the US government established The Hartford Consensus, aiming to swiftly halt severe hemorrhage and save lives and limbs.<sup>38</sup> This led to the creation of the Stop the Bleed program, training immediate responders, including the public, to identify severe bleeding and provide prompt assistance.<sup>39</sup> Lessons from the US military were integrated into the program, and the ACS Committee on Trauma played a central role in implementing the course, reaching a global audience.<sup>39-41</sup>

The impact has been substantial, with more than 2.6 million individuals in 138 countries completing the course, facilitated by numerous instructors.<sup>42-45</sup> Regulations and laws have been enacted to ensure preparedness in various settings, mandating the presence of Stop the Bleed kits containing essential supplies.<sup>44</sup> Empowered immediate responders are now equipped to intervene effectively, halt bleeding, and ensure prompt transport to trauma centers, making Stop the Bleed a crucial frontline defense in hemorrhage control.<sup>43-45</sup> By integrating this program and prioritizing circulation in trauma care practices, the medical community significantly enhances patient outcomes in cases of severe bleeding, shifting from a traditional ABC

focus to one that emphasizes immediate bleeding control to save lives and minimize hypovolemic shock.

### **Circulation-airway-breathing applications for life-saving maneuvers in patients with noncompressible bleeding**

#### **Resuscitative thoracotomy**

Resuscitative thoracotomy, also known as emergency department thoracotomy, is a divisive procedure in trauma surgery.<sup>45-49</sup> It aims to offer a last chance at survival in cases of penetrating or blunt trauma by swiftly addressing exsanguinating bleeding and cardiac tamponade, preserving organ perfusion, particularly to the brain and heart.

Guidelines have emerged to aid clinicians in resuscitative thoracotomy decisions, with patient physiology significantly impacting success rate.<sup>45-49</sup> Success is highest when patients still display signs of life, such as pupillary response, spontaneous ventilation, carotid pulse, blood pressure, extremity movement, or cardiac electrical activity. Witnessed traumatic cardiac arrests may also warrant consideration, although overall survival remains low.<sup>45-49</sup>

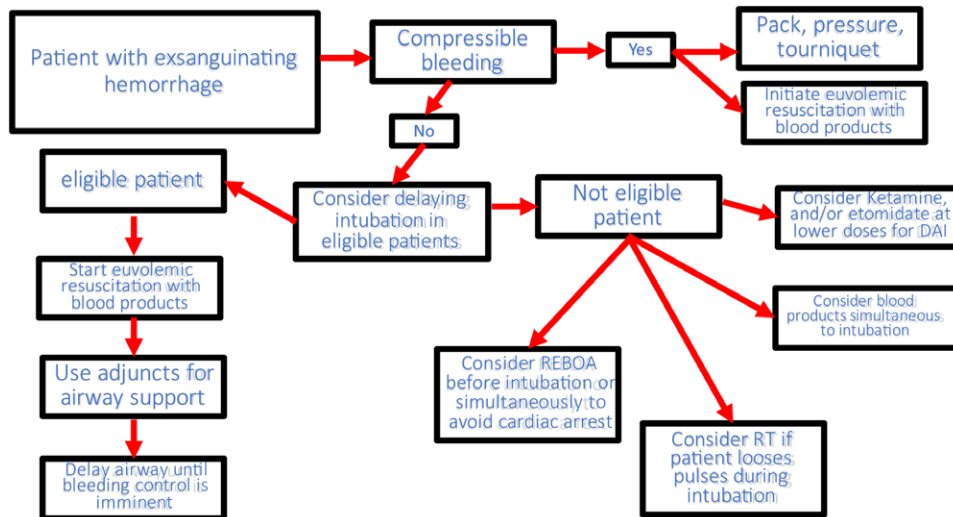
For blunt-trauma patients, ideal candidates for resuscitative thoracotomy are those who lose vital signs during transportation or on emergency department arrival, without obvious nonsurvivable injuries like severe brain trauma. Mechanism of injury and patient physiology are key determinants of success.

However, resuscitative thoracotomy may prove futile in certain scenarios. Prolonged pulselessness (15 minutes for penetrating and 10 minutes for blunt trauma), absence of signs of life at the injury scene, and asystole without pericardial tamponade indicate potential futility.

Skilled surgeons can maximize resuscitative thoracotomy's value, particularly in controlling bleeding from noncompressive injuries, such as penetrating trauma with signs of life. By incorporating resuscitative thoracotomy into circulation-focused trauma care alongside the Stop the Bleed program, healthcare providers gain a comprehensive approach to addressing severe hemorrhage, both compressible and noncompressible, in trauma cases.

#### **Other techniques to Stop the Bleed for noncompressive hemorrhage during damage control resuscitation**

In the resuscitation of patients with exsanguinating injury, immediate access to circulation and increasing blood flow are critical.<sup>50-55</sup> REBOA achieves this by placing an in-dwelling sheath for proximal aorta control. Trauma and acute care surgeons have used REBOA for more than a decade to manage hemorrhage, revolutionizing endovascular



**Figure 1.** Summary of recommendation. DAI, drug-assisted intubation; RT, resuscitative thoracotomy.

therapy.<sup>53,54</sup> REBOA enhances perfusion to critical organs and improves outcomes in various scenarios.<sup>50-55</sup>

In the case of ruptured abdominal aortic aneurysm, REBOA allows for transfemoral aortic balloon occlusion with local anesthesia, reducing blood loss from distal ruptures.<sup>50-55</sup> Lessons from endovascular surgery apply to trauma patients, because aortic occlusion enhances tolerance to shock and hemodynamic collapse. Anesthesia is crucial for definitive hemorrhage control, and REBOA patients show better tolerance to anesthesia.<sup>50-55</sup>

REBOA improves resuscitation parameters and end-tidal CO<sub>2</sub> levels in patients experiencing shock leading to cardiac arrest.<sup>50-55</sup> Recent studies support REBOA's effectiveness in reducing blood loss, possibly surpassing resuscitative thoracotomy.<sup>50-55</sup> Skillful operators and safety protocols are crucial for REBOA's success.

Incorporating REBOA into trauma care frameworks, alongside strategies like Stop the Bleed and resuscitative thoracotomy, enhances the response to exsanguinating injury, improving patient outcomes.

## Conclusions

Recognizing and prioritizing circulation in trauma patients, particularly those with severe bleeding, is of paramount importance. The traditional ABC approach to trauma care has been largely supported by expert consensus rather than scientific evidence. Recent studies and shifts in protocols have shown the potential benefit of choosing to delay intubation for eligible patients, in favor of focusing on resuscitation and swift hemorrhage control.<sup>56</sup> Physiologically, patients experiencing severe bleeding instinctively gasp for air, increasing

venous return and cardiac output. Intubation in these patients can lead to vasoconstriction loss, vasodilation, and reduced cardiac filling and output. Efforts to promote euvoletic, hemostatic resuscitation and immediate bleeding control through programs like Stop the Bleed have positively impacted patient outcomes. Strategies to address noncompressible bleeding include early resuscitation with blood products and advanced techniques like REBOA and resuscitative thoracotomy. By shifting the trauma approach to prioritize circulation and expedite hemorrhage control, we can significantly improve patient survival and outcomes. It is crucial to challenge the status quo, embrace evidence-based practices, and implement these shifts in trauma care to advance scientific knowledge and enhance patient care. We have summarized our recommendations in [Figure 1](#).

There is enough literature to support prioritizing circulation during the primary survey in patients with exsanguinating injury. For patients with noncompressible bleeding there are still opportunities to train all trauma providers in delaying intubation to prevent cardiovascular arrest.

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## Invited Commentary

### Should “Damage Control Airway Management” Be Added to Our Toolkit?

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The authors have presented a compelling argument in favor of adopting a circulation-airway-breathing approach for trauma patients with exsanguinating injury.<sup>1</sup> They should be commended for their courage in challenging the longstanding dogma of Advanced Trauma Life Support (ATLS), which advocates for an airway-breath-circulation (ABC) sequence.<sup>2</sup> It is only by questioning tradition that we can propel our field forward.

Fundamentally, ATLS represents an algorithmic approach designed to address injuries that pose the greatest immediate threat to a patient’s life. It recognizes that a patient without a patent airway will succumb more rapidly than one who cannot adequately ventilate. However, the