



# Every Minute Matters in Hemorrhagic Shock

The importance of a chain of survival framework for hemorrhagic shock, including strategies for reducing the time to intervention in the early phases of care

Randall Schaefer, DNP, RN, ACNS-BC, CEN

White Paper  
[410medical.com](http://410medical.com)



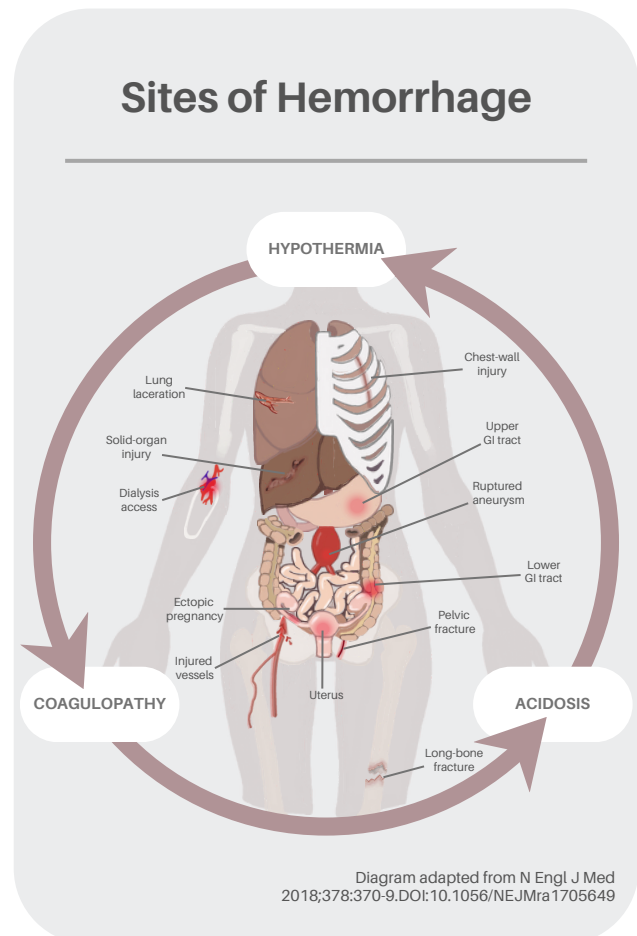
You might be able to hold your breath for one minute, but then your survival instinct kicks in and compels you to take a deep breath so that your body can receive the oxygen it needs to survive. Our critically ill patients depend on us to apply this same level of urgency to their care when minutes can make the difference between life and death.

In cardiac arrest, we know every minute is precious and that any opportunity to restore perfusion reduces the risk of tissue ischemia and death. Cardiopulmonary resuscitation and defibrillation within the first three to five minutes of collapse increase survival in sudden cardiac arrest.<sup>1</sup> The chain of survival starts with strong advocacy for early activation of 9-1-1, initiation of bystander CPR, and access to AEDs in public access areas. EMS professionals then bring advanced treatment, transport, and triage protocols to improve processes and outcomes.<sup>2,3</sup> These efforts are dedicated to reducing minutes to lifesaving interventions so that maximal patient survival can be achieved. In trauma care we have often thought of the “Golden Hour” as the critical time window for lifesaving interventions, but it is becoming increasingly clear that minutes matter in patients with hemorrhagic shock just as much as they do in cardiac arrest. Our approach to trauma resuscitation should reflect this urgency.

## Review of Hemorrhagic Shock

Hypovolemic shock results from loss of circulating blood volume leading to reduced end-organ perfusion, inadequate oxygen delivery, and ultimately, tissue death. Hemorrhage is the most common cause of hypovolemic shock and the leading cause of preventable trauma death.<sup>4</sup> The body’s primary compensatory mechanisms in the face of blood loss are increased heart rate and intense vasoconstriction, which directs the

remaining blood volume to the heart, brain, and kidneys. This vasoconstriction results in hypoperfusion and ischemia in the liver, intestines, and skeletal muscle. This complex multisystem has been described as an assault as the pathobiology of hemorrhagic shock.<sup>5</sup> In severe hemorrhagic shock, the brain and heart are also deprived of oxygen resulting in cerebral anoxia and hemodynamic collapse within minutes of the initial injury. Patients with traumatic brain injury (TBI) are particularly susceptible to the effects of hemorrhagic shock since hypotension is associated with a dramatic increase in mortality among trauma patients with associated TBI.<sup>6</sup>



# Chain of Survival for Hemorrhagic Shock

## Quickly Identifying Hemorrhagic Shock

Most deaths from hemorrhagic shock occur in the field or within 2 hours after hospital arrival and since up to 65% of patients presenting with severe hemorrhagic shock will die, early recognition and immediate intervention are the keys to reducing mortality with and improving patient outcomes.<sup>4,7</sup> Early priorities include identifying visible sources of bleeding and evaluating for signs of shock such as pallor, clammy skin, decreased mental status, increased heart rate, and decreased blood pressure. Shock index (SI) and end-tidal carbon dioxide (ETCO<sub>2</sub>) setting can also quickly and accurately identify a patient experiencing hemorrhagic shock.<sup>8,9,10,11</sup>

Shock index, which is heart rate divided by systolic blood pressure, provides an early indicator of the severity of shock even before blood pressure falls. In fact, a shock index of >1.0 may be a stronger predictor than hypotension (systolic blood pressure <90 mmHg) for identifying significant injury in trauma patients. Patients with a SI >1.0 as a first vital

measurement were more likely to require a massive transfusion protocol (MTP) activation. Similarly, patients with ETCO<sub>2</sub> levels of less than 25mmHg are three times more likely to be in hemorrhagic shock than patients with an ETCO<sub>2</sub> >25 mm Hg and may require MTP.

Once hemorrhagic shock is identified, immediate efforts at hemorrhage control and resuscitation efforts are critical. Damage Control Resuscitation (DCR) is a strategy for addressing life-threatening injuries to improve clinical stability before definitive surgical care. The principles of DCR include restoring homeostasis and preventing or mitigating the development of tissue hypoxia, oxygen debt, and coagulopathy.<sup>12</sup>

Remote Damage Control Resuscitation (RDCR) is the prehospital application of DCR strategies, pushing critical interventions closer to the point of injury and reducing the consequences of traumatic hemorrhagic shock before hospital arrival. These strategies can improve survival from hemorrhagic shock by 1) management of compressible hemorrhage control (tourniquets, direct pressure, wound packing, or resuscitative endovascular balloon occlusion of the aorta), 2) hypotensive resuscitation, 3) limiting overuse of crystalloids and colloids, 4) prevention or correction of acidosis, 5) prevention or correction of hypothermia, 6) and hemostatic resuscitation using low titer O positive whole blood or blood products.<sup>13,14</sup> The tenants of RDCR and DCR provide a framework for establishing a chain of survival for patients experiencing hemorrhagic shock.

### Shock Index:

Heart rate



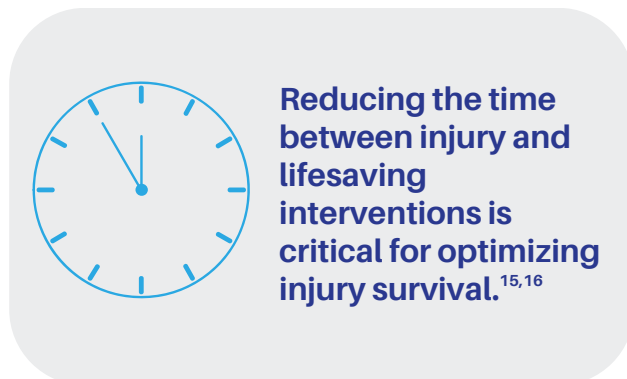
Systolic blood pressure

## Reducing Time to Treatment

Reducing the time between injury and lifesaving interventions is critical for optimizing injury survival.<sup>15,16</sup> Analogous to community-wide efforts to improve bystander cardiac arrest response, initiatives such as Stop the Bleed training and early activation of 9-1-1 can decrease the time to intervention to improve

outcomes for patients with traumatic hemorrhage.

After hemorrhagic shock is identified and basic efforts at hemorrhage control have begun, patients should receive blood products as the first-line intervention. Resuscitation should ideally occur as close to the point of injury as possible, and in fact a growing number of EMS agencies now carry blood to reduce the time between injury and treatment.<sup>17,18,19,20</sup> One hospital system has even incorporated the practice of activating MTP and operating room resources based on the assessment of air medical providers the field.<sup>21</sup>



When the patient arrives to the hospital, rapid infusion of blood products is often necessary to correct severe hemorrhagic shock. Though studies have clearly shown that every minute of delay delivering blood transfusion increases mortality, many barriers limit early effective resuscitation.<sup>15,22,23</sup> To reduce time to transfusion, larger trauma centers keep Emergency Release Blood in a refrigerator in the emergency department (ED). Hospitals with lower blood utilization rates may have to obtain blood from the blood bank after notification by the trauma team. The American College of Surgeons Trauma Quality Improvement Program (ACS TQIP) 2014 guidelines recommend that blood products should be immediately available in the ED and transfused through a rapid infuser and warmer, with care taken not to over-

resuscitate in cases of non-compressible torso hemorrhage until definitive hemorrhage control can be achieved.<sup>24</sup> Additionally, the operating room, intensive care unit, and interfacility critical care transport teams should anticipate an ongoing resuscitation and have the necessary equipment on-hand to continue warmed blood product administration.

While the ACS recommends that an MTP cooler arrive at the bedside within 15 minutes, the average time to infusion of the first blood product is often well over 15 minutes, and even this time window may be too long for many critically injured patients.<sup>23</sup> Meyer et al. (2022) studied the time for blood cooler delivery from the blood bank to the trauma room and found that every minute of delay in the arrival of blood products to the trauma bay resulted in a 5% increase in the odds of mortality.<sup>22</sup> Decreasing the time to resuscitation by prepositioning blood products in the ED is a modifiable risk factor that can reduce mortality in trauma patients.

The battle against time does not stop once the blood arrives since it then needs to be rapidly transfused to restore the patient’s circulating volume. This process can be delayed by difficulty in obtaining vascular access and the complexity or inefficiency of infusion techniques. Sullivan, et al. (2023) identified three drivers that decreased the time to blood transfusion: blood product transport from blood bank to the ED, establishment of IV access, and use of the rapid

### Signs of Shock:

Pallor

---

Clammy skin

---

Decreased mental status

---

Increased heart rate

---

Decreased blood pressure

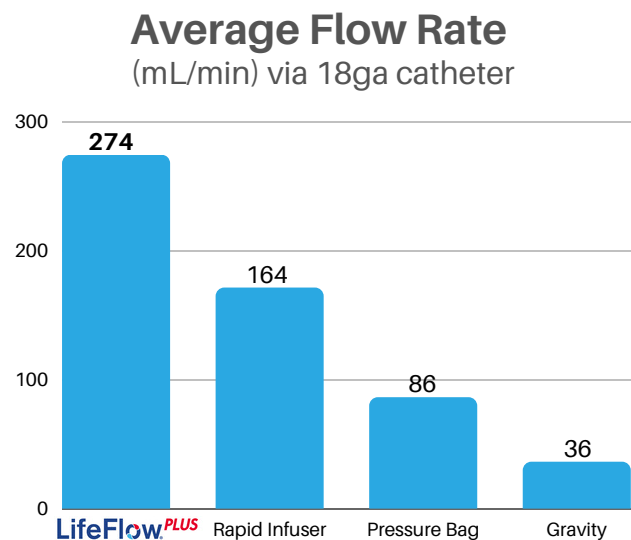


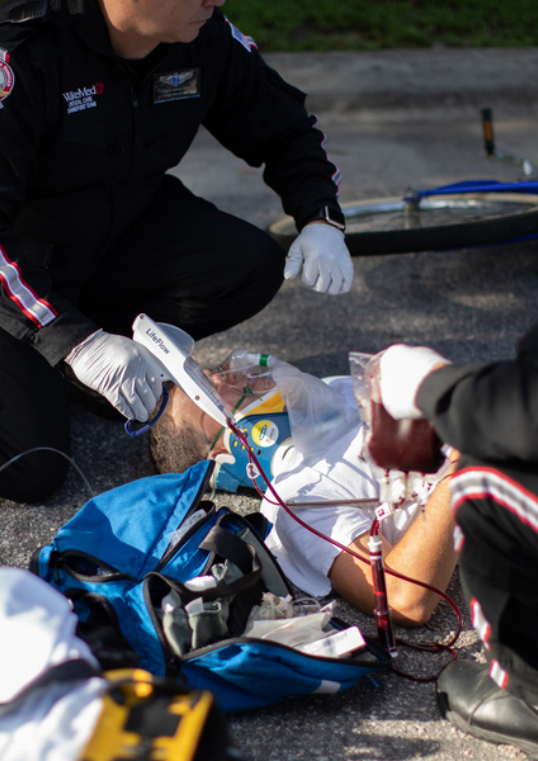
infuser.<sup>25</sup> After accounting for blood delivery delays to the ER, the subsequent most prolonged delay in the process was the staff setting up and managing the rapid infuser. This task added a 7.1-minute delay to transfusion once the blood had arrived. Despite a robust education intervention, no statistically significant changes were found in improving the time to set up and manage the rapid infuser.

Common rapid transfusion techniques include gravity, hand-squeezing, pressure bags, traditional IV pumps, and rapid infusers such as the Belmont® or Level 1®. For severe hemorrhagic shock, neither gravity, hand squeezing, nor pressure bags provide sufficient flow rate.<sup>26</sup> Pressure bags may provide an adequate initial flow rate through larger-gauge IVs, but as the blood bag empties, users must stop to re-inflate it multiple times to ensure a continuous flow rate. Challenges also arise when infusing through a small gauge peripheral IV catheter or a higher resistance vascular access device such as intraosseous access. Hospital rapid infusers are often challenging to operate, especially at low utilization sites, are large and difficult to transport, have expensive consumables, and require regular training and maintenance. Often one team member is identified to manage and troubleshoot the device during resuscitation. In the prehospital setting, rapid infusers and warmers are often incompatible. This forces a clinical decision to either warm or rapidly infuse the product. Rapid infusion solutions need to be compatible with blood and fluid warmers.

Novel devices designed for prehospital and hospital use can help decrease the interval between blood arrival and effective infusion. The LifeFlow PLUS is a lightweight, single-use, hand-operated rapid infuser that can improve the speed and efficiency of resuscitation. This device is operated by manual compression of a handle that actuates a syringe to deliver fluid or blood to the patient, then automatically refills through an automatic check valve when the trigger is released. Since it is disposable no biomedical maintenance is needed. The LifeFlow includes a mechanism to prevent inadvertent entrainment of air, as well as flexible infusion tubing to smooth flow and limit infusion pressure transmitted to the vascular catheter. This allows more rapid infusion through smaller gauge peripheral IVs. The hand operation provides tactile feedback so clinicians can control and monitor the flow rate while directly observing patient response and performing other tasks, facilitating rapid response to shock while limiting the risks of over- and under-resuscitation. With LifeFlow, one unit of blood can be delivered in approximately 2 minutes. See figure 2 for comparisons with a pressure bag and gravity.

Figure 2





## Conclusion

---

Early recognition of hemorrhagic shock and immediate provision of lifesaving interventions can improve patient outcomes and reduce the mortality associated with traumatic injury. As EMS agencies and hospitals develop a more thorough understanding of their emergency blood transfusion processes, patients will benefit from interventions that decrease the time to recognition of hemorrhagic shock and timely resuscitation with blood products. Just like with cardiac arrest, in hemorrhagic shock every minute counts from the moment of injury until all lifesaving interventions are completed.

---

### Contact Us:

---

✉ [info@410medical.com](mailto:info@410medical.com)

☎ 919-241-7900

🌐 <https://410medical.com>

## REFERENCES:

1. American Heart Association. (2018). When Minutes Matter Systems of Care of Acute Cardiovascular Conditions. American Heart Association. Retrieved December 13, 2022 from <https://www.heart.org/-/media/Files/About-Us/Policy-Research/Fact-Sheets/Acute-Care/FACT-SHEET-Systems-of-Care-for-Acute-Cardiovascular-Conditions.pdf>
2. Cone, D. C., Lee, C. H., & Van Gelder, C. (2013). EMS activation of the cardiac catheterization laboratory is associated with process improvements in the care of myocardial infarction patients. *Prehosp Emerg Care*, 17(3), 293-298. <https://doi.org/10.3109/10903127.2013.773112>
3. Pulia, M., Salman, T., O'Connell, T. F., Balasubramanian, N., Gaines, R., Shah, F., . . . Lopez, J. J. (2019). Impact of Emergency Medical Services Activation of the Cardiac Catheterization Laboratory and a 24-Hour/Day In-Hospital Interventional Cardiology Team on Treatment Times (Door to Balloon and Medical Contact to Balloon) for ST-Elevation Myocardial Infarction. *The American Journal of Cardiology*, 124(1), 39-43. <https://doi.org/https://doi.org/10.1016/j.amjcard.2019.03.046>
4. Eastridge, B., Mabry, R., Seguin, P., J, T., Uribe, P., Mallett, O., & Blackbourne, L. (2012). Death on the battlefield (2001-2011): implications for the future of combat casualty care. *Journal of Trauma Acute Care Surgery*, 73, S431-437. <https://doi.org/10.1097/TA.0b013e3182755dcc>
5. Cannon, J. W. (2018). Hemorrhagic Shock. *N Engl J Med*, 378(19), 1852-1853. <https://doi.org/10.1056/NEJMc1802361>
6. Spaite, D. W., Bobrow, B. J., Keim, S. M., Barnhart, B., Chikani, V., Gaitner, J. B., . . . Hu, C. (2019). Association of Statewide Implementation of the Prehospital Traumatic Brain Injury Treatment Guidelines With Patient Survival Following Traumatic Brain Injury: The Excellence in Prehospital Injury Care (EPIC) Study. *JAMA Surg*, 154(7), e191152. <https://doi.org/10.1001/jamasurg.2019.1152>
7. Zhu, C. S., Pokorny, D. M., Eastridge, B. J., Nicholson, S. E., Epley, E., Forcum, J., . . . Jenkins, D. H. (2019). Give the trauma patient what they bleed, when and where they need it: establishing a comprehensive regional system of resuscitation based on patient need utilizing cold-stored, low-titer O+ whole blood. *Transfusion*, 59(S2), 1429-1438. <https://doi.org/10.1111/trf.15264>
8. Bulger, N., Harrington, B., Krieger, J., Latimer, A., Arbabi, S., Counts, C. R., . . . Bulger, E. M. (2021). Prehospital end-tidal carbon dioxide predicts hemorrhagic shock upon emergency department arrival. *J Trauma Acute Care Surg*, 91(3), 457-464. <https://doi.org/10.1097/ta.0000000000003312>
9. Jehan, F., Con, J., McIntyre, M., Khan, M., Azim, A., Prabhakaran, K., & Latifi, R. (2019). Pre-hospital shock index correlates with transfusion, resource utilization and mortality; The role of patient first vitals. *Am J Surg*, 218(6), 1169-1174. <https://doi.org/10.1016/j.amjsurg.2019.08.028>
10. Kheirbek, T., Martin, T. J., Cao, J., Hall, B. M., Lueckel, S., & Adams, C. A. (2021). Prehospital shock index outperforms hypotension alone in predicting significant injury in trauma patients. *Trauma Surgery & Acute Care Open*, 6(1), e000712. <https://doi.org/10.1136/tsaco-2021-000712>
11. Zhu, C. S., Cobb, D., Jonas, R. B., Pokorny, D., Rani, M., Cotner-Pouney, T., . . . Jenkins, D. H. (2019). Shock index and pulse pressure as triggers for massive transfusion. *J Trauma Acute Care Surg*, 87(1S Suppl 1), S159-S164. <https://doi.org/10.1097/TA.0000000000002333>
12. Cap, A. P., Pidcoke, H. F., Spinella, P., Strandenes, G., Borgman, M. A., Schreiber, M., . . . Stockinger, Z. (2018). Damage Control Resuscitation. *Mil Med*, 183(suppl\_2), 36-43. <https://doi.org/10.1093/milmed/usy112>
13. Jenkins, D. H., Rappold, J. F., Badloe, J. F., Berséus, O., Blackbourne, L., Brohi, K. H., . . . Spinella, P. C. (2014). Trauma hemostasis and oxygenation research position paper on remote damage control resuscitation: definitions, current practice, and knowledge gaps. *Shock (Augusta, Ga.)*, 41 Suppl 1(0 1), 3-12. <https://doi.org/10.1097/SHK.0000000000000140>
14. Joint Trauma System. (2017). Damage Control Resuscitation. Retrieved September 3 from [https://jts.amedd.army.mil/assets/docs/cpgs/Damage\\_Control\\_Resuscitation\\_12\\_Jul\\_2019\\_ID18.pdf](https://jts.amedd.army.mil/assets/docs/cpgs/Damage_Control_Resuscitation_12_Jul_2019_ID18.pdf)
15. Deeb, A.-P., Guyette, F. X., Daley, B. J., Miller, R. S., Harbrecht, B. G., Claridge, J. A., . . . Brown, J. B. (9900). Time to Early Resuscitative Intervention Association with Mortality in Trauma Patients at Risk for Hemorrhage. *Journal of Trauma and Acute Care Surgery*, 10.1097/TA.0000000000003820. <https://doi.org/10.1097/ta.0000000000003820>
16. Shackelford, S. A., Del Junco, D. J., Powell-Dunford, N., Mazuchowski, E. L., Howard, J. T., Kotwal, R. S., . . . Stockinger, Z. T. (2017). Association of Prehospital Blood Product Transfusion During Medical Evacuation of Combat Casualties in Afghanistan With Acute and 30-Day Survival. *Jama*, 318(16), 1581-1591. <https://doi.org/10.1001/jama.2017.15097>
17. Braverman, M. A., Smith, A. A., Ciaraglia, A. V., Radowsky, J. S., Schauer, S. G., Sams, V. G., . . . San Antonio Whole Blood, C. (2022). The regional whole blood program in San Antonio, TX: A 3-year update on prehospital and in-hospital transfusion practices for traumatic and non-traumatic hemorrhage. *Transfusion*, 62 Suppl 1, S80-S89. <https://doi.org/10.1111/trf.16964>
18. Pokorny, D., Braverman, M., Edmundson, P., Bittenbinder, D., Zhu, C., Winckler, C., . . . Jenkins, D. (2019). The use of prehospital blood products in the resuscitation of trauma patients: a review of prehospital transfusion practices and a description of our regional whole blood program in San Antonio, Texas. *International Society of Blood Transfusion Science Series*, 0, 1-11. <https://doi.org/10.1111/voxs.12498>
19. Sayre, M. R., Yang, B. Y., Murphy, D. L., Counts, C. R., Dang, M., Ubaldi, P., . . . Hess, J. R. (2022). Providing whole blood for an urban paramedical ambulance system. *Transfusion*, 62(1), 82-86. <https://doi.org/https://doi.org/10.1111/trf.16749>
20. Schaefer, R., Long, T., Wampler, D., Summers, R., Epley, E., Waltman, E., . . . Jenkins, D. (2021). Operationalizing the Deployment of Low-Titer O-Positive Whole Blood Within a Regional Trauma System. *Mil Med*, 186(Suppl 1), 391-399. <https://doi.org/10.1093/milmed/usaa283>
21. Puzio, T. J., Meyer, D. E., Heft, N., Nealy, W., & Osborn, L. (2022). Continuum of Care: A Multiagency Approach to Seamless Warmed Prehospital Whole Blood Resuscitation of a Patient with Noncompressible Truncal Hemorrhage. *Prehospital Emergency Care*, 1-4. <https://doi.org/10.1080/10903127.2022.2104976>
22. Meyer, D. E., Vincent, L. E., Fox, E. E., O'Keeffe, T., Inaba, K., Bulger, E., . . . Cotton, B. A. (2017). Every minute counts: Time to delivery of initial massive transfusion cooler and its impact on mortality. *J Trauma Acute Care Surg*, 83(1), 19-24. <https://doi.org/10.1097/ta.0000000000001531>
23. Boyle, M., Py, N., Libert, N., Christment, A., Pissot, M., Dedome, E., . . . Martinez, T. (2022). Step by step transfusion timeline and its challenges in trauma: A retrospective study in a level one trauma center. *Transfusion*, 62(S1), S30-S42. <https://doi.org/https://doi.org/10.1111/trf.16953>
24. American College of Surgeons. (2014). ACS TQIP Massive Transfusion in Trauma Guidelines. Retrieved February 2 from [https://www.facs.org/media/zcjdtrd1/transfusion\\_guidelines.pdf](https://www.facs.org/media/zcjdtrd1/transfusion_guidelines.pdf)
25. Sullivan, T. M., Milestone, Z. P., Alberto, E. C., Waibel, E. M., Gestrich-Thompson, W. V., Tempel, P. E., . . . Burd, R. S. (2022). Reducing the Time to Blood Administration after Pediatric Injury: A Quality Improvement Initiative. *Pediatr Qual Saf*, 7(3), e563. <https://doi.org/10.1097/pq9.0000000000000563>
26. Piehl, M., & Park, C. W. (2021). When Minutes Matter: Rapid Infusion in Emergency Care. *Current Emergency and Hospital Medicine Reports*, 9(4), 116-125. <https://doi.org/10.1007/s40138-021-00237-6>