Prehospital point-of-care monitoring and goal-directed therapy: Does it make a difference?

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Trauma is the greatest killer during the first four decades of life in most high-income countries. Despite vast efforts in preventing accidents, the World Health Organization prognosis for trauma deaths remains pessimistic.[1] The development and implementation of trauma systems followed by quality improvement work and increased awareness have been shown to improve the quality of trauma care.[2] However, there is still room for improvements both in the prehospital and in-hospital environment and in the cooperation between the two.

The fact remains that most trauma deaths occur in the prehospital phase and even before health care personnel have arrived at the scene.[3] A significant proportion of early in-hospital deaths are still caused by exsanguination, and if severe head injuries are added, most early deaths can be accounted for.[4]

For the severely injured patient, the chain of survival starts at the time of injury, and the best possible outcome depends on optimal functioning of all links in that chain. Hypoxia, bleeding, coagulopathy, and transfusions are all independently associated with bad outcome in trauma patients.[5–8] The treatment of bleeding is to stop the bleeding and to restore circulating volume and tissue oxygenation. Hence, trauma should be considered a surgical disease, and time is of the essence until the need for surgical intervention has been clarified, which can only happen in a hospital with trauma competent capabilities.

Damage control resuscitation combines damage control surgery and optimal resuscitation in a manner that reduces physiologic compromise, requiring delays in definitive care.[9,10] The traditional lethal triad of coagulopathy, hypothermia, and acidosis, with hypothermia and acidosis being the critical drivers of coagulopathy is now being challenged by evidence demonstrating that an acute traumatic coagulopathy (ATC) is present shortly after severe trauma and before the development of hypothermia and severe acidosis occurs.[7,8] Its genesis and mechanisms have yet to be fully elucidated, but current research directions include activated protein C, hypoperfusion causing endothelial damage, and glycocalyx shedding.[11–14] ATC increases mortality up to fourfold, and the incidence depends on the population studied, ranging from less than 10% to more than 50%.[15] ATC has been shown to be detectable already on scene,[16,17] but most of the existing evidence rests on populations where blood samples were drawn up to 2 hours after injury.[15] There is convincing evidence to support early use of blood products in the resuscitation of the bleeding and coagulopathic patient.[18–20] If the right patient can be identified, it does intuitively make sense to administer blood products including coagulation factors instead of crystalloids also in the prehospital setting, if this can be done safely without delay.

All personnel involved in the treatment of trauma patients are potentially stealing time until definitive care can be provided, and focus should be on reducing the time spent and assessing the need for interventions and monitoring. The necessity for monitoring will depend on transportation time to a hospital with adequate surgical competence and treatment capabilities. Several articles have underlined the difference between a military and a civilian setting, focusing on challenges associated with time-consuming military evacuations and differences in mechanisms of injury.[21] Although the military setting might require lifesaving interventions different from those normally necessary in civilian trauma care, transportation time tends to be long also in sparsely populated countries in a civilian context. The trend toward surgical subspecialization and centralization of care will increase these challenges in the years to come. One example is the 20% decrease in the number of acute care hospitals in Norway during the past couple of years. This trend will continue, as it is impossible to recruit and maintain relevant competence in the current number of hospitals. Consequently, there will be an increased need for prehospital competence and capacity, with minimization of time spent and optimization of triage systems, monitoring, and management.

This review is limited to the monitoring and management of potentially severely injured trauma patients. Point of care is defined as tests designed to be used at or near the site where the patient is located, which do not require permanent dedicated space. Hence, all monitoring during the prehospital phase can be seen as point of care. The relevant types of monitoring will be addressed generically, without going into specific available devices.

MAIN GOALS FOR PREHOSPITAL CARE

To define needs, we need to establish goals. For the critically injured patient, the main goals should include the following: minimize on-scene time to minimize delay to an appropriate surgical facility and to recognize and perform immediately lifesaving maneuvers.

Minimum Scene Time With Minimized Delay to an Appropriate Surgical Facility

Necessary interventions should be performed during transportation whenever possible. One intervention that is often

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seen as necessary to do at the scene is control of external bleeding. The use of tourniquets has had its renaissance as a lifesaving intervention, especially in the military setting.[22] Its complications, mostly caused by inadequate use, include continued or increased bleeding, necrosis of viable tissue, potentially unnecessary amputations, and nerve injuries. Thus, robust educational programs teaching appropriate use are important. The same education should include the option of proper packing of wounds, to avoid unnecessary use of tourniquets.

If the patient is physiologically compromised and the transportation time to a major trauma center is more than 30 minutes to 45 minutes, the patient might have to be transported to a lower level of care such as an acute care hospital with surgical capabilities. In trauma system development, it becomes of utmost importance to define the requirements for these hospitals to maintain their trauma receiving capabilities. The role for an optimal triage system is to ensure that the patient is transported to the appropriate level of care while providing adequate resuscitation to improve physiology to optimize the final outcome.

Optimal Resuscitation

The aim for optimal resuscitation has to be a compromise between optimizing oxygen delivery to the cells while avoiding coagulopathy and increased bleeding.

The concept of hypotensive resuscitation originated in an urban setting, with penetrating injuries and short transportation time to a trauma center.[23] Thus, extrapolating these results to a setting with blunt injuries or blast patients in the military context, often with long to very long transportation times, could be hazardous. More recent publications on hypotensive resuscitation fail to provide the ultimate consensus conclusion.[24,25]

The concept of accumulation of "oxygen debt," increasing as a function of time spent in relative shock, draws a worrying picture for the critically injured trauma patient with long transportation/evacuation times.[26,27] This debt has to be repaid, and as the time to repayment increases, so does the risk of complications such as multiorgan failure. This might imply that "hypotensive resuscitation" should not be seen as a simple, static, and standardized approach but more as a context-sensitive intervention based not only on the blood pressure. Deliberate hypotensive resuscitation should therefore probably be balanced or more tailored to each patient. Moreover, resuscitation is likely repaid more efficiently using blood products than crystalloids, as demonstrated by early lactate clearance with the use of blood versus no-lactate clearance using crystalloids in an animal model.[27]

There is convincing evidence to support the early use of blood products in the hospital setting in the resuscitation of the bleeding and coagulopathic patient, whether this is administered as fixed ratios or guided by coagulation tests.[18–20] The challenge in administering blood products in the prehospital setting remains finding both time efficient diagnostics and logistically practical solutions for transfusion. Different types of freeze-dried plasma are becoming available.[28]

Types of resuscitation fluids to be used in the prehospital phase other than blood products will not be addressed in this review. However, in the absence of blood products, moderate use of crystalloids should probably be preferred since most colloids imply undesired effects. In particular, there is an increasing skepticism against the use of starch-containing colloids in the resuscitation of these patients.[29]

Tranexamic acid as a treatment against hyperfibrinolysis has been spread widely as a consequence of the CRASH-2 study results.[30,31] It has been included in many massive bleeding protocols around the globe and is increasingly being administered to patients also before hospital admission. There is still an ongoing discussion about the evidence to support its safety in widespread use in trauma, and several ongoing studies will aim to address this issue. In addition, the patients who would benefit from tranexamic acid might be less easy to spot in the prehospital situation, potentially leading to the administration to patients where it is not indicated.

Fibrinogen concentrate and other fibrinogen containing coagulation factor concentrates such as cryoprecipitate and prothrombin complex concentrates are also available in the market, are increasingly being used in the hospital setting, and are currently being considered for prehospital use by various services.[32–34] Again, the robust evidence supporting their safe use in these patients is lacking. The risk of giving procoagulants to potentially hypercoagulable patients, who are not proven to be bleeding, makes it important to develop robust and strict protocols. Such guidelines should preferentially be based on identified hypofibrinogenemia combined with thorough multidisciplinary evaluation programs. In addition, the time spent in administering these products should be weighed against their clinical benefit and other necessary interventions.

MONITORING POSSIBILITIES AND USEFULNESS

The need for monitoring increases with transportation time and should be tailored to the patient's needs, more than the fact that it is "doable." The most important requirements for useful monitoring are as follows: it does not increase scene time, and it can be used en route, as few devices as possible, and noninvasive whenever possible. More than anything however, it has to "make a difference," either in guiding resuscitation or in identifying the need for lifesaving interventions such as the following:

- External bleeding control
- Airway control
- Chest decompression/chest tube insertion
- Intravenous access/fluids/transfusion
- Cardiopulmonary resuscitation/cardioversion

Vital Signs

Vital signs monitoring is standard in the prehospital setting. Although vital signs have been shown to be insensitive and nonspecific in identifying the critically injured patient with massive bleeding, clinical assessment should remain the mainstay of initial care in both prehospital and in-hospital settings.[35,36] Expert opinion gut feeling is very often exact and should not be discarded in the education of future professionals. A preserved normal blood pressure can be the result of compensating mechanisms in the young bleeding patient,

whereas tachycardia does not have to be hypovolemic shock. However, like with many of the monitoring parameters, the trend is more important than exact numbers, and the sum of variables is more sensitive than each individually.

Lactate

Lactate levels are correlated to acidosis due to hypoperfusion and hypovolemic shock, and lactate has shown to correlate well with outcome and need for transfusions.[37,38] Several practical handheld devices exist for serial blood gas analyses. In contrast, a single early lactate level is only useful as a baseline for a trend and thus is probably most useful during long evacuation/transfer times. In the context of clinical suspicion of ongoing bleeding, an increase in lactate levels should prompt more aggressive resuscitation, with blood products if available.

Hemoglobin

Hemoglobin measurement is part of several point-of-care devices, with varying reliability.[39] However, the patient is bleeding blood, and the hemoglobin typically remains normal for longer than most transportation distances, despite ongoing significant blood loss. Again, the trend is more important and only obtainable during longer transfers, where hemoglobin levels should be taken in the context of lactate levels, blood pressure, and clinical suspicion of ongoing bleeding. If red blood cells are available, the target hemoglobin level should be the same as during in-hospital resuscitation until control of bleeding, greater than 7 g/dL to 9 g/dL according to the updated European guidelines.[40]

Tissue Oxygenation

As already stated, the main goal of therapy is to ensure general adequate tissue oxygenation. Pulse oximetry is designed for measuring oxygen saturation in the hemoglobin but has been shown to correlate poorly with tissue oxygenation. Other methods such as the resonance Raman spectroscopy, which largely reflects the venous hemoglobin oxygen saturation of tissue, are being explored, with promising results.[41] One pilot study in bleeding trauma patients using near-infrared spectroscopy demonstrated continuously deteriorating trends in tissue oxygenation.[42] However, the device, although noninvasive was not practical for use in the prehospital setting. A smaller handheld device has been developed and, if it demonstrates reliable results, will no doubt be a useful contribution to the prehospital monitoring arena. However, while tissue oxygenation monitoring holds promise to detect changes in oxygen delivery before changes in lactate and vital signs, no consensus exist on what tissue oxygenation levels should provoke action.

Coagulation

With the current focus on ATC and the evidence supporting early administration of blood products including coagulation factors, the question about the usefulness of coagulation monitoring in the prehospital setting naturally follows.[43,44] The massive interest around functional coagulation tests such as the viscoelastic hemostatic assays (VHAs) TEG and ROTEM has led to discussions around the possibility to use these tests in the prehospital setting to guide transfusions. The reference value defining ATC still often used in studies seeking to validate the VHA parameters is international normalized ratio.[45] There is not enough evidence to prove any effect on outcome using VHAs in early guiding of transfusion therapy or superiority to international normalized ratio.[46] In addition, the current versions of the VHAs are not close to being logistically acceptable in the prehospital setting. Even in view of a next generation handheld VHAs, the usefulness of these results will have to be weighed against the time spent drawing blood samples and getting the result somewhere on the way, probably after having made the decision to transfuse or not, anyway. Although the VHAs have proven to have limited ability to detect hyperfibrinolysis,[47] the most reasonable argument for VHAs prehospital would be to identify the hyperfibrinolytic patient in need of tranexamic acid, if future studies on tranexamic acid demonstrate increased risk of thromboembolic events. With long transportation times, a result demonstrating critically low fibrinogen levels could be defined as an indication for fibrinogen concentrate. However, the prospective trials to define safety and effect of early fibrinogen substitution are still missing.

Ultrasound

An increasing number of handheld ultrasound (US) devices are quickly becoming a tool for many clinical personnel groups involved in emergency medicine. Experienced personnel can relatively quickly and with a reasonable sensitivity diagnose a pneumothorax, evaluate position of the endotracheal tube, and to a lesser degree, evaluate volume status and rule out free fluid in the chest or abdomen.[48] Common for all of the small US devices is that their performance is inferior to the larger versions. Several publications demonstrate questionable sensitivities for simple examinations such as the FAST [Focused Assessment with Sonography for Trauma] examination, using the best larger US devices in a controlled hospital environment.[49,50] At the same time, identifying a condition does not mandate performing an intervention. For example, a simple pneumothorax in an awake patient does not require a time-consuming insertion of a chest tube unless the patient is in shock and a tension pneumothorax is suspected. In contrast, the use of US might save time by reducing the number of unnecessary interventions such as chest tubes and reduce the time spent on, for example, gaining intravascular access. Moreover, if US reveals no evidence of intra-abdominal or intrathoracic bleeding, this might be an argument to reduce the use of blood products in the prehospital phase.

CONCLUSION

The answer to the title question as to whether prehospital point-of-care monitoring and goal-directed therapy make a difference is obviously yes. However, there should be an overall focus on immediate lifesaving maneuvers and rapid transport to avoid delay to surgery. Algorithms and routines should be based on multidisciplinary system development focusing on the whole treatment chain, with ongoing needs assessment as well as a robust governance structure evaluating use and outcomes continuously connected to clinical research projects.

AUTHORSHIP

All authors have contributed significantly to the design and manuscript preparation.

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