Fluid resuscitation of the trauma patient: How much is enough?

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Patient management in the prehospital resuscitative phase after trauma is vitally important to the outcome. Early definitive care remains the essential element in improving morbidity and mortality. In Canada, where a large proportion of trauma occurs at sites distant from a trauma centre, the prehospital resuscitative phase is long and has even greater potential to affect outcome. Conventional teaching about the end points of resuscitation has promoted the concept of normalization of hemodynamic parameters with maintenance of end-organ perfusion, as measured by the hourly urine output. Recent work in patients with a closed head injury and in patients with penetrating torso trauma challenge the notion that trauma patients are homogeneous with respect to these end points. In the Canadian setting of blunt injury, where a closed head injury is usually suspected and often present, the evidence from clinical studies suggests that an aggressive approach to maintaining blood pressure is warranted. In penetrating torso injury in an urban setting, there is evidence to suggest that delaying resuscitation until hemorrhage is controlled is beneficial. More Canadian clinical trials are required in this area. In the meantime, the priorities of resuscitation must be carefully assessed for each patient and pattern of injury.

La prise en charge des patients au cours de la phase de réanimation préhospitalière après un traumatisme est d'une importance vitale pour le résultat. Des soins définitifs précoces demeurent l'élément essentiel lorsqu'il s'agit d'améliorer la morbidité et la mortalité. Au Canada, un pourcentage important de traumatismes se produisent loin d'un centre de traumatologie, la phase de réanimation préhospitalière est longue et a encore plus de chances d'affecter le résultat. L'enseignement classique au sujet des points finals de la réanimation sont à l'origine du concept de la normalisation des paramètres hémodynamiques par le maintien de la perfusion des organes terminaux telle que mesurée par le débit urinaire horaire. Des travaux récents qui ont porté sur des patients victimes d'une blessure fermée à la tête et sur des patients victimes d'un traumatisme ouvert au torse contestent le concept selon lequel ces points finals sont les mêmes chez les traumatisés. Dans le contexte canadien des blessures par traumatisme, où l'on soupçonne habituellement une blessure fermée à la tête, souvent avec raison, les données probantes produites par des études cliniques indiquent qu'une intervention agressive qui vise à maintenir la tension artérielle est justifiée. Dans des cas de blessure ouverte au torse en milieu urbain, les données probantes semblent indiquer qu'il est avantageux de retarder la réanimation jusqu'à ce que l'hémorragie soit contrôlée. D'autres études cliniques canadiennes s'imposent dans ce domaine. Entre-temps, il faut évaluer avec soin les priorités de la réanimation dans le cas de chaque patient et de chaque type de blessure.

Traumatic injury remains the leading cause of death for Canadians under 40 years of age. Blunt trauma from motor vehicle collisions, although declining in recent years, is the most common mechanism of injury by a substantial margin.[1] Penetrating trauma from gunshot wounds or stabbings constitutes approximately 10% to 15% of major trauma cases. A large proportion of trauma victims come from

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rural Canada, and in this situation the pre-hospital resuscitation phase may be longer because of the distances involved and the related transport time. These factors contribute to the higher morbidity and mortality associated with traumatic injuries occurring in rural areas.[2–4]

Resuscitation of the injured patient in a rural setting generally begins at the scene of the incident, depending on the training of the paramedical personnel available. In the majority of these situations the patient is transferred to a local hospital, where the resuscitation is taken over by the attending family physician, the emergency physician or the surgeon. Depending on the injury complex and local capabilities, the patient receives definitive care or is transferred to a trauma centre by air or ground. Specialized transport teams exist in most jurisdictions and consist of some combination of paramedical personnel, nurses and physicians. Primary response to the collision scene by an air ambulance team with direct transfer to a trauma centre does occur close to some large Canadian urban centres such as Toronto, Calgary, Edmonton and Vancouver.

Despite advanced telecommunications and rapid transport systems, the time taken to deliver the patient to a trauma centre for definitive care is significant, amounting to a median of 5.4 hours in the University of Alberta experience (326 cases of trauma with a median injury severity score of 12 or more, excluding cases transferred directly from the scene to the trauma centre).

The standard approach to resuscitation has been promulgated through the Advanced Trauma Life Support Course, sponsored by the American College of Surgeons.[5] The focus of resuscitation has been the "golden hour" (the period immediately after the injury), emphasizing the importance of airway control, assessment of breathing and maintenance of circulatory stability through the administration of intravenous fluids. The skill of paramedical personnel in controlling the airway, protecting the spinal cord, splinting fractures and establishing intravenous access is well documented.[6–8] Traditional end points of resuscitation include monitoring of vital signs, oxygen saturation and end-organ function in the form of urinary output. It is generally accepted that all of these interventions are beneficial when the pre-hospital transport time is longer than 1 hour. For pre-hospital times of 30 minutes or less, experience indicates that gaining intravenous access delays transport and the amount of fluid that can be infused is inconsequential with respect to its impact on end-organ perfusion.[6–8]

With respect to fluid administration, the trauma patient population is usually considered to be homogeneous; specific end points of hemodynamic resuscitation for specific injuries are not considered. There is general consensus that a normal blood pressure and an hourly urine output greater than 1 mL/kg are appropriate resuscitation objectives for all patients being transported and before definitive care is delivered. Recent trials in head injured patients and in penetrating torso trauma suggest that the end points of resuscitation should be individualized according to mechanism of injury and injury pattern.[9,10]

Our purpose is to address some of the issues that support immediate resuscitation in polytrauma victims to minimize injury to the gut barrier, to emphasize the importance of avoiding periods of hypotension in patients with serious closed head injury and to review the concept of delayed resuscitation in patients sustaining penetrating torso trauma.

Immediate resuscitation

The case for immediate fluid resuscitation rests primarily on the argument that in hypovolemic shock there exists a primary deficit in effective circulating fluid volume that causes inadequate cellular perfusion. In order to sustain tissue perfusion until definitive care is delivered, volume administration with isotonic crystalloids as the initial fluid has been standard practice for the past few decades. Oxygen delivery (DO_2) is a function of cardiac output (CO) times the oxygen content of blood $DO_2 = CO(Hb \times 1.34 \times \text{saturation} + 0.003 \times PO_2)$.

Cardiac output is a function of preload, contractility and afterload. In the young patient it is primarily a function of preload (volume status) since these injury victims will have normal myocardial contractility in the absence of myocardial contusion. Afterload is reduced by the vasodilating effect of increased left ventricular output induced by optimizing preload. Oxygen content is optimized by ensuring that the saturation of hemoglobin is maintained at more than 92% and that the hemoglobin concentration is adequate. In the resuscitation phase of trauma management an optimum hemoglobin for oxygen delivery is in the range of 110 to 120 mg/L (hematocrit 33% to 37%).[11] The maintenance of perfusion to vital organs in the normal range of oxygen delivery has been accepted as the top priority of resuscitation, with the sequelae of inadequate resuscitation, particularly acute renal failure, being recognized as having a significantly negative impact on outcome.[12]

Resuscitation and gut-barrier function

Recently, additional weight has been given to the argument favouring early resuscitation by recognition of the role that the inflammatory response plays in the genesis of multiple organ dysfunction. The "two hit" theory of multiple organ dysfunction suggests that a period of inadequate perfusion may in fact prime the inflammatory cascade. A second, often relatively minor, insult occurring some time later can then cause an inordinate systemic inflammatory response leading to multiple organ dysfunction, the major cause of late death in trauma patients in the intensive care unit. Experience indicates that some injuries are of such a magnitude that they will cause multiple organ dysfunction to occur from the onset. The magnitude of injury that is required to prime the inflammatory response into a susceptible state is unknown, although in all likelihood the patient's premorbid state is also an important factor.[13]

The hypothesis that the gut is the "motor of multiple organ failure" was introduced a number of years ago.[14,15] There has been extensive research into the gut–liver axis and in particular into the gut-barrier injury that occurs in hypovolemic shock. The potential for bacterial translocation has been well demonstrated in rodent models of trauma. The studies of Deitch and associates,[16–21] and Alexander and colleagues[22,23] demonstrated in their animal models that hemorrhagic shock, endotoxic shock and burn injury cause changes in the enterocyte and other components of the gut barrier that allow bacteria to translocate into the portal and systemic circulation. An ischemia-reperfusion injury has also been documented, with amelioration of this phenomenon after the administration of oxygen-free-radical scavengers and blockade of the xanthine oxidase pathway.[16–23]

The evidence for the phenomenon of endogenous bacterial translocation in the clinical trauma setting has been lacking. Work in large-animal models and humans has failed to demonstrate significant bacterial translocation after blood loss and blunt trauma.[24] In one series of 20 multiply injured blunt trauma patients no evidence of portal bacteremia was found over 5 days. In this same group of patients, the incidence of multiple organ dysfunction was 30%.[25] However, in another series of trauma patients it has been observed that the presence of endogenous gut bacteremia together with shock is associated with a fatal outcome. This suggests further that the gut barrier can be breached in severe trauma and that the bacteremia may serve as a marker of the severity of the injury.[26]

In a large-animal model developed to mimic the "two hit" scenario, the results suggested that an animal suffering a sustained period of hypovolemic shock is more susceptible to a sublethal second challenge (using intravenous endotoxin) 48 hours after the initial hypovolemic shock period. In this experiment, the animals subjected to both insults demonstrated a greater degree of hemodynamic instability and a greater propensity to systemic bacteremia of gut organisms than the control group.[27] This experimental evidence suggests that the gut–liver axis may be the site of the ignition for the systemic inflammatory response that characterizes the syndrome of multiple organ dysfunction. Furthermore, one might extrapolate that prevention of gut hypoperfusion during the resuscitation phase of the care of the injured patient is necessary if the incidence of multiple organ failure is to be decreased.

During transport of the trauma patient, systemic hemodynamic parameters are relied upon to indicate adequate perfusion. That the splanchnic circulation responds differently to low flow states is well documented.[28,29] The advent of the gastric tonometer has provided a new tool that can measure perfusion to this important regional bed. Most of the experience with the tonometer to date has been gained in the intensive care unit during the post-resuscitation phase, and its utility in the pre-hospital setting has not been determined. It may, however, find an important role in the trauma resuscitation room to help provide more definitive assessment of resuscitation to that point.[30]

Resuscitation of patients with closed head injury

In Canada, where the majority of trauma is due to a blunt mechanism of injury, the injuries are often multiple. In severe trauma, closed head injury is present in 60% of patients (patients on the University of Alberta Hospitals Trauma Registry with an injury severity score of 12 or more). The outcome from closed head injury is determined primarily by the severity of the injury and the age of the patient. Additional important cofactors are the presence of hypoxia and hypotension.[9,31–33] Recent experimental and clinical studies on closed head injuries have highlighted the importance of maintaining cerebral perfusion pressure and have suggested that the outcome may be improved if cerebral perfusion pressure is maintained at more than 70 mm Hg. Cerebral perfusion pressure (CPP) is a function of mean arterial pressure (MAP) and intracranial pressure (ICP): CPP = MAP – ICP. To use an aggressive approach in the measurement of cerebral perfusion pressure it is necessary to measure both components of this equation. MAP measurement is routine, but ICP monitoring requires the setting of an intensive care unit. It has been recommended that resuscitation guided by the CPP be carried out in closed head injury when the Glasgow Coma Score (GCS) is less than 8, with a significant grade of injury on computed tomography, and for injuries of lesser magnitude when the patient is older than 40 years.[9]

In the pre-hospital setting it is not possible to measure ICP, but in any patient with a GCS of 9 or less, the resuscitating team should assume that the ICP is elevated. To achieve a perfusion pressure greater than 70 mm Hg, the mean arterial pressure would need to be maintained in the range of 90 to 105 mm Hg, assuming an ICP of 20 to 25 mm Hg in patients with this degree of injury. The prevalence of hypotension during the transport phase of blunt head trauma, particularly in those cases originating in rural areas, is not well documented. There are many causes of hypotension during transport, some of which are iatrogenic due to sedatives, analgesics and paralysing agents. The negative impact of any period of hypoperfusion to the brain must be understood, and vigilance in preventing such episodes must be maintained.[31,34]

Delayed resuscitation

In a recent study of patients with penetrating torso trauma, Bickell and associates,[10] in a prospective study carried out in a large urban trauma system on hypotensive penetrating torso trauma victims, challenged the traditional concept that prompt intravenous fluid administration with isotonic crystalloids and packed red blood cells is beneficial when they are administered in advance of definitive surgical management of the bleeding site. The average transport time was less than 15 minutes and the average total preoperative time was less than 90 minutes. The death rate was higher in patients who underwent immediate fluid resuscitation. Based on experimental evidence[35,36] and on the results of this study, the improved survival found in those patients who had their resuscitation delayed until the bleeding had been surgically controlled was attributed to less hemorrhage from the injury site. The argument against immediate resuscitation in this setting is that it reverses vasoconstriction of injured blood vessels, dislodges early thrombus and, when given in large volumes, dilutes coagulation factors and changes viscosity to decrease the resistance to flow. All of these changes potentially aggravate blood loss or induce a secondary hemorrhage. This is an important study and should prompt many investigators to critically evaluate their practice in their own environment. Bickell and associates[10] correctly pointed out that their study was not intended to question the value of fluid administration in penetrating torso trauma but rather the timing of its administration. They concluded that in the face of uncontrolled blood loss, volume resuscitation is deleterious when given before early surgical control of the bleeding site.

Extrapolating this study to the trauma patient population in Canada must be done with great caution. First, penetrating trauma makes up a very small proportion of the trauma patient population and, second, the number of patients with penetrating torso injuries who undergo surgery within 90 minutes of their injury is even smaller. The concept that there may be an appropriate threshold blood pressure (or other easily measurable end point) below normal values, to which patients with long preoperative intervals should be resuscitated bears further thought and investigation.[37]

Conclusions

The primary objective of any trauma system is early and appropriate definitive care. To delay is to leave the patient more susceptible to multiple organ dysfunction and other complications of critical illness.[38,39] The trauma patient population is very heterogeneous in terms of complexity and type of injury. In blunt trauma, particularly with associated closed head injury, immediate resuscitation remains the accepted standard of care.

For transport times of less than 30 minutes an emergency medical system should “scoop and run,” delivering the patient to the trauma centre where resuscitation and definitive care can be delivered simultaneously. For transport times greater than 60 minutes, it is possible to stratify the multiply injured patient population into those in whom maintenance of regional perfusion to the gut and kidneys is best maintained with an effective circulating fluid volume and those who require defence of blood pressure while avoiding overhydration (head, spine and chest injuries). The end points of resuscitation in this longer-transport group must be individually monitored by ongoing evaluation of the patient’s clinical status, and it is worth reiterating that iatrogenic causes of hypotension (sedatives and analgesics) must be avoided. Organ perfusion, as demonstrated by urinary output greater than 1.0 mL/kg, is an appropriate end point. In the presence of severe head injury (GCS less than 9), the maintenance of an MAP in the range 90 to 105 mm Hg should ensure adequate cerebral perfusion. Unfortunately, if this is achieved with large volumes of isotonic fluids, exacerbation of cerebral edema and its sequelae may cause significant morbidity and mortality. It is in this group of patients that newer modalities of resuscitation (hypertonic saline with dextran, inotropes) may prove beneficial; however, clinical studies addressing these issues in patients with prolonged transport times have not yet been reported.

The concept of delayed resuscitation in penetrating torso trauma deserves more investigation in the Canadian experience. Animal models of controlled blood loss suggest that the gut barrier remains physically intact for up to 4 hours with an MAP of 40 mm Hg.[24,27] Experimentally it appears, however, that this degree of shock primes the inflammatory response to make it more susceptible to a second insult within 48 hours. What the threshold blood pressure might be and what threshold duration of hypoperfusion is required to prime the inflammatory cascade is unknown and likely is multifactorial in nature.

The timing and degree of resuscitation required varies according to the type and severity of injury and the proximity to definitive care. Individual patients must be assessed for the priorities of treatment according to their injury pattern. Few well-controlled prospective studies on fluid resuscitation and outcomes applicable to the Canadian trauma experience have been reported. On reviewing the literature, what is apparent is that delays in definitive care lead to greater morbidity and mortality and that periods of hypotension and hypoxia in association with a severe head injury have a drastic impact on outcome. The tendency to treat all injury victims in a similar manner, to the same end points, needs to be challenged. In light of the recent literature it appears that an even more vigorously individualistic approach to the assessment of the trauma patient's priorities should be taken.

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SESAP VIII Critique
Critique SESAP VIII

Items 282 and 283

Patients with diabetes mellitus are predisposed to develop foot ulcers because of their peripheral neuropathy, and go on to develop secondary infection of these ulcers because of their impaired immune system. Some patients have systemic signs of infection, including fever and glycosuria, while local signs may be minimal. Aggressive treatment, including hospitalization, early surgical exploration, and intravenous antibiotics, is important if the foot is to be saved.

Physical examination of the foot is frequently misleading as a means of determining the extent of infection. These infections are usually polymicrobial and are often associated with gas-producing organisms. A plain roentgenogram of the foot may identify gas as well as evidence of bone destruction. The status of the foot circulation can usually be determined by physical examination and subsequent vascular laboratory studies. In patients with vascular disease, arteriography may be performed subsequently when infection has been controlled. A gallium scan will not provide any more useful information than a foot roentgenogram. These patients require early exploration and wide debridement of necrotic tissue in the foot. The foot can often be salvaged even when the initial assessment would appear to indicate the necessity for early amputation.

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