Practical translation of hemorrhage control techniques to the civilian trauma scene

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This article examines how established and innovative techniques in hemorrhage control can be practically applied in a civilian physician-based prehospital trauma service. A "care bundle" of measures to control hemorrhage on scene are described. Interventions discussed include the implementation of a system to achieve simple endpoints such as shorter scene times, appropriate triage, careful patient handling, use of effective splints and measures to control external hemorrhage. More complex interventions include prehospital activation of massive hemorrhage protocols and administration of on-scene tranexamic acid, prothrombin complex concentrate, and red blood cells. Radical resuscitation interventions, such as prehospital thoracotomy for cardiac tamponade, and the potential future role of other interventions are also considered.

INTRODUCTION

The last decade has seen a significant increase in publications on, and interest in, the management of trauma-related hemorrhage. Progress has been made at all levels—from a better understanding of hemorrhage at a basic science level to changes in practical procedures performed on bleeding patients in the emergency department. Clinicians have seen the introduction of older concepts like hypotensive resuscitation[1] adopted into mainstream resuscitation practice[2] and are now considering how an improved understanding of acute traumatic coagulopathy[3] can guide practice. Damage control resuscitation and surgery, the early use of blood and blood products, and practical hemorrhage control techniques with topical hemostatic agents and tourniquets have been rapidly moved forward in military trauma practice and in many civilian trauma services. Consensus on best civilian practice after interpretation of recent progress and data is not straightforward but has been attempted recently.[4] This article examines the efforts of a civilian physician–led trauma service to integrate established and developing concepts of hemorrhage control into routine practice.

The appropriate interventions and management of hemorrhage in a prehospital service depend upon the skill level of the providers, case-mix, and timelines relevant to the system. These "fixed variables" of an Emergency Medical Services (EMS) system have been described recently by an international expert group.[5] Based on this reporting structure our service is an urban physician-led prehospital trauma service serving a daytime population of around 10 million in an area of approximately 5000 km^2. A doctor–paramedic team is delivered by helicopter (in the daytime) and by fast response car at night. The system employs flight paramedics as emergency medical dispatch authority for the physician–paramedic scene response. The physician–paramedic team is always dispatched in addition to a standard land ambulance response. Dispatch criteria target patients with severe injury. Case-mix is dominated by blunt trauma but the proportion of penetrating trauma has risen steadily[6] and currently equates to approximately 20% of missions. The service attends an average of 5-6 trauma patients per day. Doctors are experienced emergency physicians or anesthesiologists with in-hospital anesthetic and emergency medicine experience and prehospital training.

The philosophy of a physician-led trauma service influences the level of care provided. Few would disagree that patients who require immediate surgery for hemorrhage control should be transported to a hospital with appropriate facilities without delay. Unfortunately this is not always possible and analysis of scene times reveals that in many systems a significant proportion of trauma victims spend the majority of the first hour after injury outside hospital.[7,8] In geographically isolated areas and with patients who are trapped this time may be further

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extended. The development of regional trauma systems in some countries has potentially increased prehospital times with the introduction of "bypass to major trauma center" policies. Although direct transfer is associated with improved survival,[9,10] systems like ours are set up because it is recognized that care is often suboptimal before arrival in hospital and that time-critical clinical problems may need to be addressed before arrival in hospital. Airway management is a controversial area, which illustrates this problem. In the United States, a review of available publications by the Eastern Association for the Surgery of Trauma[11] noted that "seven studies indicate that 70% of patients in need of emergency tracheal intubation do not receive it until trauma center arrival." This suggests that a large percentage of critically injured patients have "a delay in optimal care." In one study of trauma patients who required intubation after arrival in hospital, half were for "immediate indications," e.g., airway obstruction, severe hypoxemia, or cardiac arrest, which were already present on arrival in the emergency department.[12] UK experience demonstrates similar problems.[13] In a proportion of trauma patients, major hemorrhage is, like airway compromise, a time-critical clinical problem that also requires rapid attention after injury to avoid preventable death.

The concept of "Critical Care without walls" was applied by Hillman in 2002 to patients with critical illness who happened to be on wards outside a critical care area.[14] He noted that the patient's location rather than acute needs appeared to determine the level of care delivered. This model was used to develop hospital medical emergency teams, but it is a concept that we use in prehospital critical care—if a trauma patient has a condition which is life-threatening and can be effectively treated by the attending team it should be dealt with immediately. Another "critical care" concept that influences our practice is the "care bundle." This approach combines interventions in the belief that the sum of carefully applied interventions is likely to be more effective than individual components. Our "pre-hospital hemorrhage care bundle" attempts to combine all interventions of proven benefit to achieve early hemorrhage control and deliver them to appropriate patients. The potential obstacles to this approach include the development of a dispatch system that reliably delivers the team to bleeding patients, the availability of providers with the required competencies, effective transport to scene, and the resource and system support to deliver the required interventions.

The rigorous measurement of "care bundle" compliance is a vital part of this approach. The parallel processes of quality assurance (or clinical governance) and innovation are key to trauma systems. Ensuring that the basics are done properly and auditing practice of established (often basic) methods of hemorrhage control is as important as the development and implementation of new approaches. This article will use several examples of hemorrhage control techniques to examine how established and innovative practice can be integrated into routine care.

ACHIEVING GOOD SCENE TIMES, APPROPRIATE TRIAGE, AND APPROPRIATE GOOD PRACTICE STANDARDS

The importance of short scene times in trauma patients, particularly those with shock, has been emphasized in many publications and guidelines. However, scene times may be misleading. Transport of a patient with immediate time-critical but treatable pathology may lead to poor outcomes.[15] Time from injury to definitive treatment, e.g., laparotomy or craniotomy in the minority of patients who need immediate surgery, is a more important time interval. Direct transfer to a trauma center may be more likely to achieve this. Where critical interventions have been carried out before arrival in hospital the time in the emergency department may also be reduced. "Direct to CT" policies where the patient is taken to CT before arrival in the emergency department are being explored in several UK centers in selected patients accompanied by a prehospital physician. It has recently been established that CT scanning can even be achieved outside hospital.[16] In the United Kingdom, prehospital times in nontrapped trauma patients attended by ambulance crews have been reported to be in the region of 40-45 minutes, and the National Confidential Enquiry into Patient Outcome and Death reported even longer prehospital intervals.[13] Our service aims to achieve scene times of less than 10 minutes for awake patients with penetrating trauma and 25-35 minutes for patients with blunt trauma who require on-scene interventions. In 2011 mean scene times for 346 awake trauma patients were 11.4 minutes for penetrating trauma and 36 minutes for patients with blunt trauma where interventions (e.g., prehospital anesthesia, procedural sedation, chest decompression) were carried out on scene. Triage to a center capable of treating the identified injuries is important. This has been formalized in the United Kingdom with the development of Major Trauma Centers and trauma decision triage tools. In common with US experience[17] moderate over-triage is expected to avoid any under-triage. Under-triage is very uncommon in our system (less than 1%) and is always carefully examined at quality assurance meetings. A key national guideline related to hemorrhage was published in 2004 in the United Kingdom by the National Institute of Clinical Excellence, which recommended 250 mL crystalloid boluses in patients suspected of bleeding and who had absent peripheral pulses. Our service was compliant with this recommendation before it was published.

GENERAL MANAGEMENT OF BLEEDING

A recently published Canadian National Advisory Committee statement on general approaches to bleeding for in-hospital trauma patients demonstrated the difficulty of reaching consensus in this controversial area.[4] Published military experience has been highly influential in changing practice, but the exact relevance of military experience to civilian trauma practice has been questioned in several areas.[4] Our local prehospital practice committee carefully evaluated the available evidence and has implemented techniques on the basis of potential benefit and lack of harm.

Tranexamic acid administration

An example of an established in-hospital treatment that has been recently introduced into routine prehospital practice is the administration of the antifibrinolytic agent tranexamic acid. The large multicenter randomized controlled CRASH 2 trial published in 2010 enrolled more than 20,000 patients.[18] The study suggested a mortality benefit in trauma patients when given in the first 3 hours after trauma but administration within 1 hour of injury was most beneficial. The patient group targeted for this intervention is that with patients suspected of major hemorrhage. Optimal outcome for this group of patients requires minimal transfer time to a major trauma center and no delay for additional interventions on scene. The compromise between these two competing principles for us was to administer the drug during transport. The first 60 patients in our system who received the drug had completed administration by a mean 58 (95% confidence interval: 3.88) minutes post injury.

Patient handling

A more established concept in trauma management is that of gentle patient handling to prevent clot dislodgement—particularly in patients with a fractured pelvis.[2] Careful examination of prehospital standard ambulance procedures in our system some years ago led to a change of practice to achieve best practice. Before the change, injured patients were log rolled onto a long spinal board on scene and then log rolled again on arrival at hospital to remove the board. Simple analysis of rotational movement with potential for clot dislodgement revealed that a patient found injured with a fractured pelvis in the semi-prone position would have 510° of rotation before being supine on a hospital trolley. Changing practice to reduce movement involved insertion of the two halves of an orthopedic scoop stretcher on scene and removal with only careful counter-traction in the emergency department. This resulted in a reduction of rotational movement from 510° to 170° in the example described above. Similar benefits may be achieved with other bleeding sites, e.g., multiple rib fractures. Attention to smaller sites of blood loss, e.g., basic suturing of scalp lacerations may help prevent cumulative blood loss. Constant review of current practices may deliver similar benefits, which translate to deliver recent innovation.

BLEEDING FROM SPECIFIC ANATOMICAL SITES

Techniques have been developed and adapted to treat hemorrhage at specific anatomical sites. Some are techniques routinely used in EMS systems around the world—applied strictly according to standard operating procedures and reviewed regularly. Other techniques have been developed to deal with our specific patient case-mix and available provider skill set.

Pelvic fractures and maxillofacial hemorrhage

Severe hemorrhage and death from severe pelvic fractures is seen regularly in our blunt trauma population particularly among cyclists and motorcyclists. Rapid application of pelvic splints has been standard practice for more than 15 years. Commercially available splints have replaced the original elasticated splints. Maxillofacial hemorrhage is often encountered in conjunction with head injury. A combination of techniques is used to immobilize and splint fractures and restore normal anatomy. Patients are usually intubated. The tracheal tube provides a degree of splinting as well as airway protection. The facial skeleton is splinted with a well-fitted rigid cervical collar (mandible). Two bite blocks are applied between the molars (mandible/maxilla) and two nasal epistats (Xomed, Medtronic, Minneapolis, MN) are inserted into the nasal cavities with one or both inflatable balloons inflated. The maxilla may be gently realigned where necessary when the bite blocks are inserted.

External hemorrhage control

Military practice has led to a resurgence of interest in tourniquet application for limb hemorrhage[19] and the use of topically applied hemostatic agents in addition to efficient compression dressings. We introduced the Combat Application Tourniquet and Celox gauze dressings into practice 3 years ago and have recorded 23 tourniquet and 11 Celox gauze uses in the same period. Clinical case review does not confirm any obvious benefit in terms of visible hemorrhage reduction. This may be because of the later application and different mechanisms of injury in civilian practice compared with military practice. Noncompressible hemorrhage in junctional zones can also be compressed with insertion and inflation of the balloon of a Foley catheter.[20]

Prehospital thoracotomy and treatment of expanding intracranial hematoma

Relatively small volumes of blood accumulating in anatomically restricted spaces containing vital organs can rapidly cause death. Pericardial tamponade after penetrating trauma and expanding intracranial hematoma are key examples.

Immediate thoracotomy for cardiac arrest associated with penetrating trauma is an established emergency department intervention.[21] It is also established that emergency department thoracotomy for patients who sustain cardiac arrest on scene is essentially futile.[15,22] This futility was also seen in our system. The first reported prehospital resuscitative thoracotomy was performed in 1988.[23] The rarity of prehospital doctors in the United States prevented development of the procedure. In our system where a doctor–paramedic team is routinely delivered to the scene of penetrating trauma the concept was developed and has been routine practice for many years. Where mortality was 100% we now have survival rates of 18% in selected patient groups with excellent neurological outcomes.[24] Sixteen survivors have been produced in our system and several from other EMS systems.[25,26] Survival appears to depend on time from cardiac arrest to relief of tamponade and the nature of the injuries. All survivors had cardiac tamponade.

Expanding intracranial hematoma is a time-critical emergency. Control of ventilation and use of hyperosmolar solutions with immediate transfer to a neurosurgical center has been the mainstay of prehospital management in our system. The evacuation of intracranial hematoma outside neurosurgical centers is virtually unheard of in the United Kingdom. It has been noted that evacuation of hematomas by nonneurosurgeons in geographically isolated areas may produce survivors while similar patients transferred to trauma centers may miss the opportunity for early evacuation.[27] Reexamination of this intervention to provide evacuation in patients with fixed dilated pupil(s) before arrival in a neurosurgical center may be appropriate. The availability of perforator drill bits with a clutch mechanism may make the procedure much safer. In our system patients with a head injury and reduced level of consciousness can now have point-of-care testing for international normalized ratio (INR) if it is suspected that they are taking warfarin. Using the INR result and a dosing normogram, prothrombin complex concentrate is administered en route to hospital in an attempt to reverse anticoagulation as early as possible and limit the size of the intracranial hematoma.

EARLY ACCESS TO BLOOD AND BLOOD PRODUCTS

Massive transfusion policies for patients identified to have severe bleeding are mandatory in UK major trauma centers.[28] The concept has been extended and evolved into trauma-specific "code red" policies in our and other centers to activate a predetermined blood and blood product package for bleeding trauma patients. The policy is activated by the hospital trauma team leader and, in an attempt to have blood and blood products available on arrival at the emergency department, the policy can be activated from scene by the attending prehospital doctor. The policy is activated on the basis of suspected or confirmed active hemorrhage and a recorded systolic blood pressure of <90 mmHg; failure to respond to a crystalloid fluid bolus (usually administered by the ambulance service) is also taken into consideration.[29] These simple activation criteria have been monitored to establish whether they correctly identify patients with bleeding and a transfusion requirement. Initial data[29] demonstrated that in the first 30 months of operation approximately 3.6% of trauma missions generated a "code red" request. Analysis of available data on 92 "code red" patients received in our hospital demonstrated that the patients had a high mortality rate (31.5%) and were severely injured (Median Injury Severity Score 27). Red blood cells (RBCs) and fresh frozen plasma (FFP) were always available on patient arrival. Records of blood product use revealed that overall a mean of 11.6 units of RBCs and 7.2 units of FFP were administered. Survivors received less blood products than those that died. This preliminary data suggest that simple physiological criteria identify severely injured patients who require transfusion. The criteria are necessarily very basic and adopted to make prehospital decision making straightforward. It is our intention to compare the sensitivity and specificity of the prehospital criteria with established in-hospital criteria.[30]

In April 2012 our service became the first UK civilian prehospital service to routinely carry RBCs to the scene. In conjunction with our blood transfusion service a reliable system has been developed where four units of O negative RBCs are carried in lightweight refrigerated containers with temperature monitors. The blood is returned to the blood bank if unused after 24 hours. In the first 3 months of operation 23 blood transfusions were given on scene in approximately 4% of trauma missions. A pretransfusion sample is taken before transfusion and delivered to the receiving emergency department. Consultant telephone authorization is obtained before commencement of transfusion. Prehospital FFP has not been added to the blood because of the logistical difficulties and cost. The current change of practice is therefore the use of RBCs in place of 250 mL boluses of crystalloid rather than extension of full emergency department transfusion protocols into the prehospital phase of care. We are keen to establish whether this change of practice influences the almost 100% mortality rate of traumatic cardiac arrest secondary to hypovolemia previously reported in our system.[31] We are carefully looking at developments in dried FFP,

point-of-care rotational thomboelastometry testing, and fibrinogen administration to consider possible applications in our service. Safety considerations make the use of fresh whole blood in prehospital civilian UK practice highly unlikely in the near future although effective technologies to improve the safety of fresh whole blood may change this position.

The future

The examples discussed in this article demonstrate a wide range of techniques applied to traumatic hemorrhage in general and to hemorrhage at specific anatomical sites. We believe that quality assurance of existing basic and more advanced techniques is as important as the use of new or innovative techniques. New point-of-care testing and diagnostic methods are improving and are increasingly available on scene. Use of these new technologies will inevitably increase scene times and must provide the possibility of useful change in management to justify any additional delay. Technological advances that may be applied to on-scene hemorrhage control in the near future include emergency preservation resuscitation,[32] resuscitative endovascular balloon occlusion of the aorta,[33] and extracorporeal cardiac life support.[34] These techniques may well provide exciting opportunities to produce survivors from a group of trauma patients who, with current conventional treatments, have 100% mortality.

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