Resuscitation and anaesthesia for penetrating trauma

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Purpose of review

The worldwide burden of trauma is increasing, but is unequal between nations. Trauma targets the young and productive in society and imposes a major burden on the health infrastructure. This review provides a distillation of practice in a busy urban trauma centre dealing with large volumes of penetrating trauma.

Recent findings

The anaesthetist holds a pivotal role in the management of penetrating injury; the requirements of prompt airway control, early delivery to theatre and control of a physiologically brittle patient can be challenging. Recognition that attempts at definitive surgery in exsanguinating patients may do more harm than good has made surgery a tool of resuscitation rather than an end in itself.

Summary

Depending on where they practice, clinicians are more or less likely to encounter patients with gunshot wounds. However, adherence to basic principles and attention to the details of temperature control, invasive haemodynamic monitoring, blood product therapy and effective communication should translate to improved outcomes for patients after penetrating trauma.

Keywords

penetrating trauma, anaesthesia, review

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Abbreviations

ERT	emergency room thoracotomy
rFVIIa	recombinant activated human clotting factor VII

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Introduction

In 1990, about five million people died worldwide as a result of injury [1] and it is estimated that by the year 2020, 8.4 million people will die every year from trauma [2]. However, volumes and patterns of injury vary considerably around the world; overall homicide rates range from 1.0 per 100 000 in established market economies to 44.8 per 100 000 in sub-Saharan Africa [3•]. While the United States saw a nationwide decrease in the annual non-fatal firearm-related injury rate of 40.3% between 1993 and 1997, with a 21% decline in the annual firearm-related death rate during the same period [4], South Africa is battling with what has been described as 'a malignant epidemic of trauma' [5]. Penetrating trauma in South Africa in the 1980s was predominantly from stab wounds; however, in recent years gunshot wounds have become much more common (Fig. 1). The total number of deaths that occur in South Africa due to unnatural causes is estimated to range from 65 000 to 80 000 per annum (accounting for between 12% and 15% of the more than 500 000 deaths that occur annually from all causes) [6•]. Most of the deaths from injuries in South Africa occur among non-white males in the economically active age range of 15–44 years and the leading cause of these deaths for males is homicide; more than half of all the homicides are inflicted by firearms and one-third by sharp instruments [6•]. In our trauma unit near the centre of urban Johannesburg, approximately 160 priority-one patients undergo resuscitation per month, with 55% of cases being due to penetrating injury [7•].

Airway

Penetrating injuries to the neck are a common feature in our emergency departments. On arrival, patients are evaluated using established advanced trauma life-support (ATLS®), principles [8] and classified as either requiring immediate operation or to be managed with careful observation supported by selective application of investigations. Patients are resuscitated in the Trendelenburg position, to prevent air embolism, an uncommon but avoidable cause of death after major cervicomediastinal venous injury [9]. The principle clinical features mandating early tracheal intubation are acute or worsening respiratory distress, airway compromise from blood and secretions, extensive surgical emphysema, tracheal deviation by haematoma, and decreasing level of consciousness [10]. Intubation can be challenging, as pre-oxygention may be less effective than usual and if mask ventilation is attempted, air may be forced into the subcutaneous tissue causing further distortion of the anatomy [11•]. Although rapid sequence induction has

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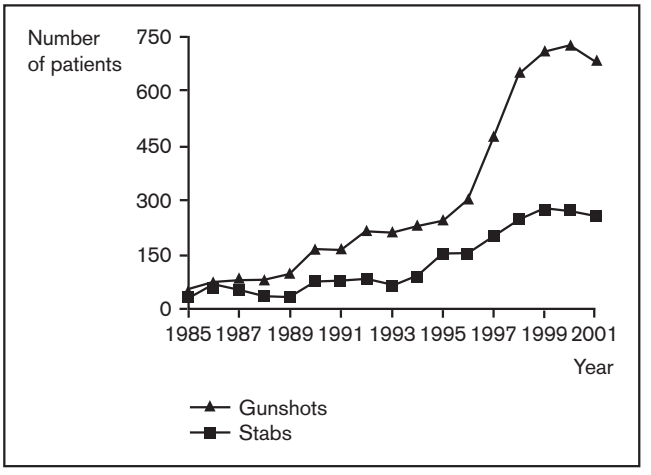
Figure 1. Priority-one resuscitations



Penetrating trauma at the Johannesburg Hospital between 1985 and 2001.

Figure 2. Foley catheter used to tamponade bleeding in gunshot neck

reported success rates of between 65% and 98% [9,10], the use of neuromuscular blocking agents in the presence of a haematoma in the neck may result in total obstruction of the airway as loss of muscle tone may lead to a 'can't intubate, can't ventilate' scenario [9]. Also, the drugs used in rapid sequence induction may have undesirable effects on cardiac output and blood pressure. In Johannesburg, a combination of morphine and midazolam is used to allow pre-oxygenation and facilitate intubation when possible, with selective use of suxamethonium by doctors only. If the clinical setting is more urgent, we advocate the use of etomidate or ketamine as induction agents, because of their favourable haemodynamic properties. Neuromuscular blockers are not used in penetrating injuries where it is suspected that the airway is injured or may be difficult.

Patients with penetrating neck injury taken directly to the operating room are those with severe external haemorrhage, expanding or pulsatile haematomas, patients who are haemodynamically unstable despite resuscitation or patients with stridor, haemoptysis or air bubbling through a neck wound, particularly in the absence of a pneumothorax [9,12]. Severe bleeding is controlled by external pressure or by inserting a Foley catheter into the wound and inflating the balloon (Fig. 2) [13]. If use of a Foley catheter is attempted, intubation must be carried out as a priority, as tamponade of bleeding is never absolute and distortion of the airway is inevitable.

Approximately 7–10% of cases of penetrating neck injury will involve the respiratory tract [12,14] and those with airway trauma have a mortality of up to 33% [15]. Direct airway injury may be controlled by intubation through the wound (Fig. 3).

Viral pathogens are common in trauma patients [16•] and full barrier precautions must be universal; patients with penetrating injuries to the airway are often uncooperative due to a combination of hypoxia, hypotension and intoxication and can spray and aerosolize blood all over the resuscitation bay.

Gunshot wounds to the face may result in airway compromise due to the presence of blood and saliva in the airway and/or haematoma and oedema of the upper airway; approximately 20% of these patients require an emergency airway and up to 10% of patients with a gunshot to the face will have an associated cervical spine injury [17]. If the patient is conscious then we turn them on their side or sit them up and allow blood and secretions to drain away. The patient is given a hand-held sucker and instructed in its use to clear the oropharynx. Significant soft tissue swelling is inevitable if the projectile has crossed the floor of the mouth or the

Figure 3. Direct intubation through a stabbed neck

Figure 4. Gunshot to the right side of the face requiring an emergency surgical airway

tongue and airway protection is almost always required (Fig. 4). If emergency airway protection is not required, the patient is closely observed and will often be stable enough for oropharyngeal intubation with tracheostomy performed in theatre with the first maxillofacial surgical intervention.

Intubation facilitated by fibre optic bronchoscopy is the gold standard for any patient in whom the airway is suspected to be difficult: direct airway injury can be definitively diagnosed and it allows for placement of an endotracheal tube into one of the bronchi if there is a major injury to the opposite side [18•,19]. The patient should be allowed to breathe spontaneously for as long as possible and ideally should undergo a gas induction of anaesthesia followed by bronchoscopy; a rigid scope may be useful if there is blood or copious secretions in the pharynx.

Figure 5. Gross haematoma after a stabbed neck

Elective intubation by the most experienced anaesthetist available is undertaken by a variety of means: awake fibreoptic intubation in the sitting position being our method of choice. However, nasotracheal intubation is not attempted in the presence of midface gunshot fractures. Expertise in this technique is vital, as false extratracheal placement has been reported in a patient with a tracheal injury despite use of a fibre optic scope and mistakes can lead to fatal airway compromise [20].

Surgical cricothyroidotomy remains a life saving intervention [17,21]; if, however, there is significant haematoma in the neck then this intervention may become more complicated (Fig. 5). The teeth are always carefully inspected and cervical and chest radiographs

examined if there is a chance of aspiration of broken or avulsed teeth.

Cervical spine injury

Unstable cervical spine injury without neurological injury is very rare in penetrating neck injury [22]. The majority of patients with gunshot wounds to the neck either have obvious neurological fallout or have no neurological injury. In a series of 346 patients with penetrating neck injuries from our institution, 9% had cervical spine injury [12]. Although laryngoscopy is known to cause cervical spine movement at a point of injury irrespective of in-line immobilization or traction, strenuous efforts are made to immobilize the cervical spine during all emergency airway manoeuvres [23]. The focus must be for timely control of the airway, but this should not be achieved at the expense of cervical spine immobilization [24••].

Emergency room thoracotomy

Even in level-1 centres in the USA, emergency room thoracotomy can have dismal results. A review of 160 consecutive patients undergoing emergency room thoracotomy (ERT) documented a survival rate of 2.7% [25]. Experience in Johannesburg has confirmed the futility of ERT in patients after blunt trauma, but those patients with penetrating chest injuries may have a survival rate of up to 20% [26]. The survival rate for patients with penetrating abdominal trauma who require ERT is approximately 7% in our setting [26]. ERT is a maximally invasive procedure, undertaken in a rush and without full facilities; in an environment of high prevalence of HIV, liberal use of the technique is not warranted.

A physiological classification has been suggested to guide clinicians (Table 1) [27]. Ladd and colleagues [28••] recently validated this approach and recommend that ERT should be withheld for patients of class I or II at scene, or class I on arrival at hospital (see Table 1). There remain some enthusiasts for emergency thoracotomy in the pre-hospital setting but we are reluctant to support this approach in an urban setting [29•].

Fluid resuscitation

The debate over which fluid to use for resuscitation is ongoing. In a systematic review of randomized controlled trials comparing colloid and crystalloid resuscitation in critically ill trauma patients, the relative risk of death with colloid was 1.3 (95% CI 0.95–1.77) [30]. The results of a second similar review were even more discouraging with a relative risk of death with colloid of 2.6 (1.1–5.9) [31]. Several reasons have been advanced to explain these findings, but they are consistent with the hypothesis that expansion of the circulating volume in trauma patients with ongoing bleeding is harmful.

An awareness of the experimental and clinical evidence that fluid administration before surgical control of haemorrhage may actually worsen bleeding and increase mortality after penetrating injury has led members of the Cochrane Injuries Group to describe current resuscitation practice as 'potentially harmful and at best experimental' [32•]. Intravenous fluids have been shown to inhibit platelet aggregation, dilute clotting factors, modulate the physical properties of thrombus and cause increases in blood pressure that can mechanically disrupt clot [32•]. Animal models have demonstrated reductions in mortality with resuscitation to a mean arterial pressure (MAP) of 40 mmHg versus more normal pressures (80 mmHg) [33]. In a study of hypotensive patients with penetrating injuries in Houston, significantly more patients survived when they were randomized to a policy of fluid resuscitation delayed until haemorrhage had been controlled than with immediate fluid administration [34]. The methodology of this study has been criticized [32•] and the concept of delayed administration of fluids may not be universally applicable. The recent Fluid Restriction in Trauma study described a trial including 110 patients who where hypotensive at least once in the first hour after injury [35•]. Patients were randomized into two groups: the first underwent resuscitation to a conventional systolic blood pressure of above 100 mmHg and the second to a lower systolic blood pressure of 70 mmHg. Patients with both blunt and penetrating injuries were included and while there was a significant difference in recorded systolic blood pressure between the groups (114 mmHg versus 100 mmHg) the mortality was the same. These results highlight the difficulties in clinical research in this area and the weakness of using an isolated recording of low blood pressure as a marker for haemorrhagic shock. The study groups were homogeneous and included 13% of

Table 1. Classification of physiological status

Class I No signs of life	Class II Agonal	Class III Profound shock	Class IV Mild shock
Full cardiorespiratory arrest: No electrical activity, asystole, absent corneal, pupillary and gag reflexes	Electromechanical dissociation: Any electrical activity on ECG with no palpable pulse or blood pressure	Blood pressure <60 mmHg	Blood pressure between 60 and 90 mmHg

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patients who stopped bleeding spontaneously after non-operative management.

In a well-designed study from Philadelphia, Clarke and colleagues [36••] found a strong correlation between delay in the resuscitation area and increased mortality in hypotensive patients with major abdominal injuries requiring laparotomy. The probability of death showed a relationship with both the extent of hypotension and the length of time in the emergency department for patients who were in the emergency room for 90 min or less. The probability of death increased as much as 1% for each 3 min delay in the emergency room. Information about volumes of pre-surgery fluids was not available in this study but it may be that delay to surgery also implies greater infusion of fluid. South African experience supports this premise and patients with penetrating torso injury should be given minimal emergency room interventions with the goal of speedy surgical arrest of bleeding [37]. The priority is for securing of the airway, placement of a large bore central catheter and blood analysis for arterial gases and cross-match. We are always mindful of haemo-pneumothorax and place chest drainage tubes without waiting for radiographic confirmation. Imaging can be helpful, but more often slows the resuscitation and is not helpful in an exsanguinating patient.

Intraoperative decision making

Up to 35% of deaths after civilian trauma result from massive haemorrhage into the torso [38•] and in modern warfare, death from exsanguination occurs in approximately half of all deaths [39]. After major trauma with exsanguination, a vicious cycle of metabolic derangement characterized by acidosis and hypothermia leads to a severe coagulopathy, which, when clinically evident, is often difficult to treat and leads inexorably to the patient's demise [40]. This has been described as the 'exsanguination syndrome' and intraoperative appearance of coagulopathy is very highly predictive of death [41••]. Prevention of onset of this syndrome by a rapid surgical procedure where the minimum is done to stop haemorrhage and limit or contain contamination is referred to as damage control surgery [42]. Following this 'incomplete' surgery vigorous attempts are made to restore normal physiology in an intensive-care unit setting and when stable, the patient is returned to theatre for anatomical reconstruction.

In these situations, the anaesthetist is the critical decision-maker. All too often the surgeon can become focused on his or her attempts to gain control of a difficult surgical situation and then may want to proceed to provide definitive surgical treatment. Signs of impending physiological decompensation must be recognized before the limit of the patient is exceeded and the vicious cycle becomes irreversible. Communication is vital to ensure that the surgeon is aware of the degree of physiological compromise, as the decision to perform damage control surgery should be made as early as possible.

Temperature control is critical in patients with major penetrating injury; high volume fluid warmers are used as routine and a heated air blanket should be placed over the head, shoulders and upper extremities, with a second blanket over the lower limbs. The upper body air blanket may be in the way of attempts to achieve appropriate vascular access, or sternotomy, but if it can be positioned once lines are placed it is extremely useful. Irrespective of the urgency of the situation, the patient's head must be covered to prevent heat loss. Raising the ambient temperature of the operating room and use of warmed anaesthetic gases is also helpful (Fig. 6).

The recognition of patients who need damage control can be learned [43••]. Trajectory of projectiles, physiological compromise on presentation and intraoperative parameters predict the onset of the exsanguination syndrome and the need for damage control [41,43••,44•]. Indications to abort surgery include an arterial pH below 7.2 or temperature under 34°C, estimated blood loss of 5 l or massive transfusion requirements [41]. The degree of surgical expertise, critical care availability and the volume of other cases pending should also be taken into consideration and an honest dialogue between surgeon and anaesthetist is vital. Early institution of damage control is thought to confer improved results [43••].

Blood transfusion

Although the availability of blood for transfusion is known to be a major determinant of outcome after injury [45], packed red blood cell transfusions have been shown

Figure 6. Damage control patient

Temperature control is not easy with this exposure. The patient had a gunshot wound to the liver.

to have significant immunosuppressive potential, and transmission of fatal diseases through blood supply has been extensively documented. Packed red blood cell transfusions are an independent risk factor for post-injury infection and multiple organ failure [46]. Initially, transfusion was felt to be a surrogate for injury severity, but it has been found to be a robust and independent predictor of postoperative complications. Attitudes to transfusion have changed substantially since the early 1990s and at least one large trial found that using a restrictive blood transfusion protocol in place of a more traditional one improved survival [47]. These findings have led to a paradigm shift with respect to blood transfusion: whereas the traditional view was that anaemia by itself was a sufficient indication for transfusion, the current consensus is that a second indication must be present in addition to a decreased haemoglobin concentration.

Diverse clinical experience has substantiated the feasibility of autotransfusion in trauma [48]. Autotransfusion eliminates the infectious, allergic, and incompatibility problems of stored blood, an important concern because of the HIV/AIDS pandemic. However, when large amounts of collected blood are reinfused, a consumptive coagulopathy and platelet dysfunction may occur [49]. These risks may outweigh the benefits of autotransfusion in the critically injured patient who has multiple potential bleeding sites. In Johannesburg, we use commercially available chest drains, which allow us to collect and reinfuse blood after it has been filtered [50].

Novel adjuncts

Intravenous administration of recombinant activated human clotting factor VII (rFVIIa) has an established place in prevention of bleeding in haemophiliac patients undergoing surgery. In a hypothermic, coagulopathic animal model, rFVIIa reduced blood loss and restored abnormal coagulation function when used as an adjunct to damage control surgery techniques [51•]. Seven massively bleeding, multi-transfused, coagulopathic trauma patients have also been treated with rFVIIa after failure to achieve haemostasis with conventional means. The coagulopathic bleeding resolved in all patients, coagulation parameters improved dramatically and four of seven patients survived [52••]. Decreasing haemorrhage by inducing hypercoagulability at the bleeding site holds great potential and randomized, multinational trials have commenced. RFVIIa is also being considered as a pre-hospital adjunct as, in an animal model, when given early after injury it is thought to cause temporary cessation of bleeding and improve haemodynamics [38•].

Conclusion

Depending on where they practice, clinicians are more or less likely to encounter patients with gunshot wounds. Experience in high-volume centres has led to the recognition of exsanguination as the initiator of a syndrome that may lead to an irreversible cycle of hypothermia, acidosis, coagulopathy with resulting physiological derangement and death. The anaesthetist is a key figure in the chain of survival and the most precious resource that a major trauma patient possesses is time. The anaesthetist should recognize his or her responsibilities in early control of the airway, limited pre-surgical infusion of crystalloid and temperature preservation. Dialogue between anaesthetist and surgeon and early institution of damage control techniques should translate to improved outcomes for this most brittle sub-group of trauma patients.

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