Trauma anaesthesia and critical care: the post trauma network era

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Key points

Trauma should be managed in networks with a major trauma centre at its hub.
Anaesthetists provide a key role from point of injury to rehabilitation in the management of the severely injured.
Damage control resuscitation underpins initial patient management in major trauma.
The severely injured in intensive care are at risk from sepsis and multi-organ failure.
Robust audit and governance structures need to be in place for the severely injured to assess outcomes and improve standards.

Trauma forms a core component of the curriculum for both the Royal College of Anaesthetists (RCA) and Faculty of Intensive Care Medicine (FICM) because of the role that anaesthetists have in the management of every stage of major trauma, from point of injury to rehabilitation. Major trauma is defined as an injury severity score (ISS) >15, although this is not a cut-off and the injury pattern itself also has a bearing on the survivability. (Calculation of the ISS is shown in Table 1).

The commonest cause of major trauma in the UK is road traffic collisions, resulting in >20,000 cases and ~5400 deaths.

In 2000, the Royal College of Surgeons recommended that major trauma should be organized into networks, with smaller units acting as feeder hospitals for major trauma centres. It further suggested that each region needed a major trauma plan, defining a definitive pathway for severely injured patients; including ambulance protocols, hospital capabilities, and inter-hospital transfer guidelines.

A 2008 National Health Service review concluded that the arguments for major trauma centres were compelling. This in turn led to the appointment of a national clinical director of trauma in 2009 and the formulation of a Department of Health (DoH) regional trauma networks programme. They recommended that to maintain major trauma credentials, a hospital needs to see >650 major trauma cases per year.

The London Trauma System commenced on April 1, 2011 and many other regions in the UK have or are currently developing their own systems. It is recognized that currently some regions do not have all acute surgical specialties represented requiring cross network cooperation to ensure equal access to treatment for time-critical interventions.

In the 2000–2009 time period, the numbers of critical care beds in England increased by >1300 but capacity issues remain and ICNARC data indicate that only two-thirds of critical care moves to major trauma are for clinical reasons.

Pre-hospital care

Most patients are treated at scene by ambulance service personnel and transported to hospital by land. The increase in Helicopter Emergency medicine providers (21 Air Ambulance charities utilizing 30 helicopters) has meant more patients have a medical attendant at scene. Additionally, there are voluntary sector providers including the British Association of Immediate Care Schemes (BASICS), often staffed by anaesthetic-trained personnel.

There has been a shift away from training paramedics in endo-tracheal intubation at scene, with more emphasis now on prioritizing oxygenation in the first instance. Emergency pre-hospital medical attendants are trained in advanced airway management (including emergency tracheotomy). On scene cardiovascular management consists of balancing the need for adequate vital organ perfusion against the risk of exacerbating further bleeding from injuries with the associated problems of haemodilution and coagulopathy. The consensus view in the pre-hospital setting is that the absence of a radial pulse boluses of 250 ml of saline should be titrated until a radial pulse returns. It should be recognized that patients with head injuries form a distinct group and higher arterial pressures will be required to maintain cerebral perfusion. (systolic arterial pressure >90 mm Hg).

DoH Guidance in 2010 has resulted in the formation of Medical Emergency Response Medical Teams (MERIT) to facilitate the provision of care near to an incident. These teams have senior doctors (often anaesthetists) with advanced airway and resuscitation skills.

Emergency department management

Trauma teams

After arrival in the Emergency Department (ED), the seriously injured should be received by a dedicated trauma team. There needs to be a
If any region scores a 6, the score is automatically set at 75.

Severe injury ISS

outside the normal operating theatre environment.

vital factors in the success or failure of interventions performed

conduct of RSI. Non-technical skills and communication can be

either in the ED or ICU. Most events in the ED were related to the

ing that one in four major airway events reported to the Royal

usually requiring rapid sequence induction of anaesthesia with

mised airway with a definitive airway device may be a priority,

initial responsibility is of airway management; securing a compro-

from the anaesthetic department or intensive care unit (ICU). The

Anaesthesia service representation in the trauma team may come

planning definitive management.

Table 1 Calculation of the ISS

1. The ISS based on the Abbreviated Injury Scale (AIS), a global severity scoring

   system classifying each injury in every body region on a six-point ordinal scale

   according to its relative severity.

   (i) Minor
   (ii) Moderate
   (iii) Serious
   (iv) Severe
   (v) Critical
   (vi) [Maximal/unsurvivable]

2. For ISS calculations, the body is divided into six regions from the AIS. (Maximum

   score 5 for each)

   (a) Head or neck—including cervical spine
   (b) Face—including facial skeleton, nose mouth, eyes, and ears
   (c) Chest—thoracic spine and diaphragm
   (d) Abdomen or pelvis contents—abdominal organs and lumbar spine
   (e) Extremities or pelvic girdle—pelvic skeleton
   (f) External and other

   The three highest scores (x, y, and z) from the AIS are squared and added to form the
   ISS

   \[ \text{ISS} = x^2 + y^2 + z^2 \] (range 3–75)

   Severe injury ISS > 15

   If any region scores a 6, the score is automatically set at 75

proper handover from the pre-hospital care attendants to the trauma

team. In general, an ED consultant or senior registrar will assume

the role of team leader and ensure that a primary survey is performed

as soon as possible. There should be anticipation of events and con-

current activity at this stage to ascertain the injury pattern and begin

planning definitive management.

Role of the anaesthetist

Anaesthesia service representation in the trauma team may come from

the anaesthetic department or intensive care unit (ICU). The

initial responsibility is of airway management; securing a compro-

mised airway with a definitive airway device may be a priority,

usually requiring rapid sequence induction of anaesthesia with

manual in-line stabilization of the cervical spine. It is worth reflect-

ing that one in four major airway events reported to the Royal

College of Anaesthetists, 4th National Audit Project survey occurred

either in the ED or ICU. Most events in the ED were related to the

conduct of RSI. Non-technical skills and communication can be

vital factors in the success or failure of interventions performed

outside the normal operating theatre environment.

Indications for tracheal intubation are varied but usually fall into

one of three broad categories: a compromised airway because of

facial trauma or swelling, a compromised airway because of a

decreased conscious level and major injuries requiring relief of dis-

tress, and on-going advanced resuscitation and surgical intervention.

Induction of anaesthesia is optimal if cardiovascular stability is

maintained where possible. Ketamine is often used for this reason

but incautious use can still provoke severe hypotension in the

shocked patient. Pragmatically judicious use of whatever induction

agent the anaesthetist is most familiar with is the best course of

action when considering the risks and benefits.

Cardiovascular management

Ideally severely injured patients should have two large bore routes of

i.v. access. In the event of difficult peripheral access, central venous

access should be attempted. The presence of a cervical collar or

pelvic binder may influence the decision about where to site central

venous access. Femoral lines may be preferable in head injury

patients and internal jugular or subclavian lines are favoured in

lower limb, pelvic, or major abdominal injuries. Invasive arterial

pressure monitoring should ideally be placed as soon as possible but

should not delay time-critical interventions which will stop uncon-

trolled haemorrhage.

Emerging concepts in trauma resuscitation

Coagulation abnormalities are common in major trauma. Acute trau-

matic coagulopathy (ATC) is an endogenously caused dysfunction

which can start within minutes of major trauma. Evidence

suggests that this is not a consumptive process, as was previously

thought. The mechanism appears to be modulated by tissue damage,

systemic hypofusion and inflammatory mediator release, disrupt-

ing the equilibrium between the vascular endothelium, platelets, and

pro/anti-coagulant factors. The presence of this coagulation disrup-

tion early after major injury is a predictor for increased risk of organ

impairment, infection and death. As initial resuscitation commences,

hypothermia, metabolic acidosis, consumption of clotting factors,

and the administration of hypo-coagulable fluids all exacerbate the

initial coagulopathy which then manifest as a trauma induced coagu-

opathy. The early administration of tranexamic acid is now recom-

mended following the results of the Clinical Randomisation of an

Antifibrinolytic in Significant Haemorrhage (CRASH-2) trial in 2010.

Modification of the extent of the inflammatory response to a major

injury is also likely to reduce progression to other significant morbid-

ities, such as acute lung injury and cerebral oedema. There is retrospect-

ive data to support this and it is an area of on-going active research.

A suggested trauma haemorrhage protocol is shown in Figure 1.

Damage control resuscitation

Damage control resuscitation (DCR) is now a well established

concept that aims to balance the need for vital organ perfusion

against the risk of exacerbating coagulopathy and bleeding. DCR

was introduced into the UK Defence Medical Services (DMS) in

2007 with the paradigm ABC (Catastrophic haemorrhage

control; Airway; Bleeding; Circulation). Permissive hypotension

and haemostatic resuscitation leading onto damage control surgery

(DCS) form the basis of DCR (Table 2).

Permissive hypotension

Permissive hypotension refers to the strategy of restricting fluid re-

suscitation and permitting a lower than normal perfusion pressure
until any haemorrhage is controlled. This management strategy ideally will have started in the pre-hospital care phase. The exact arterial pressure target remains controversial. European guidelines suggest systolic arterial pressures of 80–100 mm Hg with the exception of severe traumatic brain injuries (TBI) or spinal injuries which require systolic arterial pressures consistently >90 mm Hg.

Uncertainty still prevails about optimum management in patients with multi-system blunt injuries and TBI. The DMS has been
Table 2  Damage control in trauma

1. Initial DCR
   **Goal:** To maintain perfusion to vital organs thus avoiding a low physiological reserve state without exacerbating the ill effects of fluid resuscitation like coagulopathy and hypothermia
   **Interventions**
   - Restricted crystalloid infusion
   - Early 1:1:1 transfusion of PRBC, FFP, and platelets. Consider cryoprecipitate and other specialized coagulation treatment after discussion with haematologist
   - Tramexamic acid (CRASH-2 trial protocol: loading dose 1 g i.v. >10 min started within 8 h of injury followed by an infusion of 1 g >8 h)
   - I.V. calcium supplementation
   - Correct electrolyte imbalance (e.g. management of hyperkalaemia)
   - Active warming of patient and transfusion fluids

2. Damage (and haemorrhage) control surgery
   **Goal:** To arrest bleeding, clean contamination, restore, and maintain normal physiology. A plan should be in place to halt surgery if it continues for >90 min as the risks start outweighing the benefits in prolonged procedures
   **Anaesthetic interventions**
   - Optimize ventilation to achieve adequate tissue oxygenation
   - Fluid, blood, and blood product transfusion based on clinical indications and laboratory results
   - Warm fluids, warm ventilation gases, and convective warming blankets
   - Close communication with surgical team and critical care unit
   **Interventions**
   - Invasive BP monitoring (aim to keep SBP 80–100 mm Hg in adults until bleeding surgically controlled)
   - Regular ABGs (aim to keep pH >7.25, lactic acid <5, ionized Ca >1 mmol/litre –1, Hb >7 g dl –1)
   - Central body temperature monitoring (aim to keep core temperature >36 °C)
   - Near patient (TEG/ROTEM if available) and laboratory tests of coagulation data including
   - Serum fibrinogen level

3. On-going management and monitoring in ICU
   **Goal:** To optimize and maintain physiology with a view to on-going treatment planning
   **Interventions**
   - Correction of coagulopathy
   - Correction of body temperature
   - Optimization of vital organ perfusion by revision of systemic arterial pressure target
   - General stabilization and care
   - Preparation and planning for definitive surgical repair, including transfer, and retrieval to specialist centres

**Monitoring during DCR**

Laboratory tests including full blood count, prothombin time, activated partial thromboplastin time and fibrinogen level are usually readily available and commonly used. However, they are often unhelpful in guiding large volume blood transfusions because of the delay in sending samples and obtaining results. Near-patient testing using TEG (thromboelastography) or ROTEM (rotational elastometry) are quick and provide a real-time picture of clot formation and lysis. Regular arterial blood gas (ABG) measurement also helps guide the adequacy of resuscitation and the need for calcium supplementation and dextrose/insulin (to treat hyperkalaemia).

**Damage control surgery**

DCS arose from the recognition that severely injured patients often lack the physiological reserve to survive complex, prolonged definitive surgery in the early stages. A three-phase approach is employed that starts off with an abbreviated resuscitative surgery the aim of which is rapid control of haemorrhage and contamination. Definitive repairs are deferred until the patient is stable. The patient is usually then transferred to ICU for continued active re-warming, correction of coagulopathy, and acidosis. Once normal physiology is restored the patient can have planned definitive surgical management.

**Role of interventional radiology**

In some centres interventional radiology (IR) can offer a minimally invasive alternative to surgery in controlling haemorrhage in certain patients. Trans-catheter arterial embolization of bleeding vessels or stent-grafting of larger ruptured vessels are both established techniques which may be employed in the bleeding trauma patient. In haemodynamically stable trauma patients, IR has a role in the management of solid organ injuries (liver spleen and kidney). In unstable patients, IR can be effective in stopping haemorrhage from pelvic fractures, where open surgery can be technically challenging. It is also worth noting that most radiology suites are located remote from the main operating theatre suite, increasing the anaesthetic challenges of potentially managing a critically injured patient in an isolated environment.

**Operating theatre, interventional radiology or intensive care? Decision making trees**

Once the primary survey has been completed and immediate life threatening injuries identified (and dealt with if possible in the ED),
a decision needs to be made about the destination of the severely injured patient. This may include the need for immediate surgery (operating theatre), radiology (for IR or further diagnostic imaging) or transfer to the ICU for a continued period of stabilization.

Full imaging will help to identify the complete injury pattern and aid in decision making. Chest, pelvic, and cervical spine X-rays can be done early in the ED but may only give limited information. FAST ultrasound scanning (Focused Assessment with Sonography for Trauma) can be performed rapidly (within 3 min with an experienced operator). A positive scan shows as an anechoic (dark) strip within dependent areas of the peritoneum. In the right upper quadrant between the liver and kidney (Morrisons pouch), in the left upper quadrant around the spleen (perisplenic) and in the pelvis blood pools behind the bladder (retrovesicular space or Pouch of Douglas). The pericardium is also seen to assess for the presence of a cardiac tamponade. The presence of a positive FAST scan in a stable patient should prompt an urgent CT scan.9

Multi-slice CT scanning is the optimal imaging modality in poly-trauma and it is often appropriate to perform a head to pelvis whole body CT. With intubated patients, where early clinical cervical clearance is not possible, this can be achieved by a combined head and neck CT and the application of an agreed clearance protocol.

Haemodynamically unstable patients with blunt abdominal injuries and positive FAST scanning should be transferred directly to theatre (or IR) without undergoing CT scanning. The presence of blood in the pericardium and haemodynamic compromise may result in immediate thoracotomy in the ED.

### On-going management of the major trauma patient, transition to intensive care

Trauma patients come to the ICU for further resuscitation, stabilization and sometimes advanced organ support. Patients with complex injuries usually require a prolonged course of ICU management.

A complete re-evaluation of all patients should occur in the ICU, the goal being to avoid missing any injuries which may have gone un-noticed in the resuscitation phase of care. This is termed the tertiary survey and it is recognized that those patients with TBI are at greatest risk of having an occult injury which can ultimately have a large impact on morbidity (Table 3).

In this prolonged phase of care, sepsis and progression to multi-organ failure are the greatest risks. Efforts should be made to prevent infection and to treat it promptly if it occurs. A rising creatine kinase should provoke a thorough review to rule out compartment syndrome. It is often a signal that further surgical exploration and tissue debridement is required and surgical review should be sought as soon as possible; untreated this can lead to acute kidney injury and renal failure with the consequent failure to progress in some patients. Basic infection control measures should not be forgotten, and daily microbiology team review. Early enteral feeding to maintain gut integrity is essential, where possible and fasting for scheduled surgery should be minimized. Daily physiotherapy, focusing on the respiratory system and range of motion in all joints is also essential. The patient’s perspective of an optimal outcome is return to their pre-injury function and the whole remit of ICU management (beyond prevention of death) is to give the patient the optimal opportunity to benefit from the rehabilitation phase, which follows discharge from ICU (Table 4).

### Ward management and rehabilitation of the trauma patient

Trauma patients may require a prolonged course of treatment, multiple surgical procedures, and ward-based rehabilitation. Some injuries may require transfer to regional specialist centres for on-going management. Anaesthesia involvement in these patients is usually

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**Table 3** Checklist for trauma patients in the ICU

<table>
<thead>
<tr>
<th>Trauma specifics</th>
<th>Tertiary survey completed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>All imaging completed and reported?</td>
<td>Surgical plans for the spectrum injuries?</td>
</tr>
<tr>
<td>TBI injury guidelines followed?</td>
<td>Cervical spine cleared?</td>
</tr>
<tr>
<td>Infection control</td>
<td></td>
</tr>
<tr>
<td>Strict adherence to hand hygiene?</td>
<td>Non-sterile venous access lines changed?</td>
</tr>
<tr>
<td>Non-sterile venous access lines changed?</td>
<td>Appropriate and necessary antibiotics?</td>
</tr>
<tr>
<td>Ventilated patients</td>
<td>Head-of-bed elevation?</td>
</tr>
<tr>
<td>Low tidal volume ventilation indicated/ employed?</td>
<td>Oral care protocol?</td>
</tr>
<tr>
<td>Head injury BP/ICP/PaCO₂ targets</td>
<td>Spontaneous breathing trial to enable ventilatory weaning?</td>
</tr>
<tr>
<td>Spontaneous breathing trial to enable ventilatory weaning?</td>
<td>Sedation and analgesia protocol?</td>
</tr>
<tr>
<td>Nutrition instituted and optimized?</td>
<td>Is paralysis justified?</td>
</tr>
<tr>
<td>Pain management: pain well controlled?</td>
<td>Pressure area protection optimized?</td>
</tr>
</tbody>
</table>

**Table 4** Sepsis targets for trauma patients in the ICU

<table>
<thead>
<tr>
<th>Clinical targets</th>
<th>Measure serum lactate/base excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain adequate glycaemic control best and safest for circumstance?</td>
<td>Obtain blood cultures before antibiotics are given</td>
</tr>
<tr>
<td>Maintain an adequate central venous pressure</td>
<td>Reduce time to broad spectrum antibiotics where clinically indicated</td>
</tr>
<tr>
<td>Maintain an adequate central venous oxygen saturation</td>
<td>Treat hypotension, elevated lactate with fluids, or both</td>
</tr>
<tr>
<td>Three management goals</td>
<td>Maintain adequate central venous pressure</td>
</tr>
<tr>
<td>Adhere to the Surviving Sepsis Campaign guidelines</td>
<td>Maintain an adequate central venous oxygen saturation</td>
</tr>
<tr>
<td>Maintain adequate glycaemic control</td>
<td>Minimize inspiratory plateau pressures</td>
</tr>
</tbody>
</table>

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related to surgical planning and pain management, both acute and chronic.

A National Audit Report in the UK in 2010 showed that hospital with dedicated trauma wards and trauma consultants resulted in better patient outcomes, reduction in surgical delays and wasted bed days. It also revealed that the current provision of trauma rehabilitation is not comprehensive. Trauma networks also have a responsibility for public engagement and injury prevention strategies as part of their remit.1,10

Trauma clinical governance

Without measuring patient outcomes it is not possible to institute targeted quality improvement measures for the trauma cohort. Outcome studies performed in Australia have shown that the introduction of a trauma network can reduce hospital lengths of stay and increase the number of patients living independently 6 months post-injury. In the UK, the majority of hospitals dealing with major trauma contribute data to the Trauma Audit Research Network for independent analysis and case-mix comparison with other centres. Within hospitals, there are a variety of approaches to measure and improve outcomes; these include regular morbidity and mortality meetings, individual case reviews, and trauma peer review committees. Trauma networks all tend to have steering committees with an identified network lead to ensure that cross-network procedures are standardized where possible, to optimize outcomes.

Trauma training for anaesthetists

Taught courses in trauma management include Advanced Trauma Life Support, the European Trauma Course and those offered by BASICS. Trauma networks will ideally set their own trauma education strategy which should include a combination of clinical exposure and more formal teaching. For anaesthetists there is no substitution for a trauma exposure while in a training grade or via the trauma network for the more established practitioner.

Summary

The delivery of trauma care in the UK is changing with the introduction of the regional trauma networks. New developments in the understanding of the patho-physiology and clinical management of major trauma have changed the approach to initial management, with a shift to lower volume fluid resuscitation and damage control strategies.

Anaesthetists can be involved in the entire patient chain of survival, from pre-hospital care all the way through to rehabilitation. Sound clinical knowledge and technical skills are vital to ensure the best possible outcome for severely injured patients. Over recent years, the importance of anaesthetic non-technical skills has been increasingly recognized.

Declaration of interest

None declared.

References


Please see multiple choice questions 25–28.