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Early management of the severely injured major trauma patient

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Editors's key points

- The trauma team must function as a unit with effective leadership and a clear understanding by team members of their roles.
- Repeated briefing and review maintains clinical through the numerous transitions involved in the care of trauma patients.
- A higher rate of failed intubation is seen in trauma patients than in other groups.
- During intra-operative care, the patient's status should be reviewed every 10–30 minutes and the surgical plan modified if necessary.

The major trauma team relies on an efficient, communicative team to ensure patients receive the best quality care. This requires a comprehensive handover, rapid systematic review, and early management of life- and limb-threatening injuries. These multiple injured patients often present with complex conditions in a dynamic situation. The importance of team work, communication, senior decision-making, and documentation cannot be underestimated.

Keywords: patient care; resuscitation; teams; wounds and injuries

Major trauma networks have recently been developed in England to provide optimal management of the severely injured patient. Numerous reports have highlighted the past problems in trauma care in the UK and the recent reorganization seeks to address these deficiencies.[1–3] This reorganization is based on the improved survival and outcomes observed when severely injured patients present to specialized (major trauma) centres (MTCs) that treat sufficient numbers and have a coordinated, multidisciplinary team to receive, resuscitate, and provide definitive care.[4 5]

This restructuring of major trauma care is the first nationally coordinated change trauma services since the inception of the National Health Service 60 yr ago and the first attempt at developing a national system to provide high-quality trauma care for the population in England. Twenty-six regional trauma networks have been established; each network has been designed to best serve the local geography, population and infrastructure. The East Midlands Major Trauma Network covers a population of 4.3 million and consists of one MTC with five supporting trauma units (TU). Severely injured patients are identified using a triage tool and are taken directly to the MTC if the journey time is <45 min or to the nearest TU if the patient has an immediate life threatening injury. Patients >45 min from the MTC are taken to the nearest TU for resuscitation, evaluation, and detailed triage. Secondary transfer then will take place to the MTC if required. Other hospitals with A&E departments, designated as Local Emergency Hospitals, which do not have the facilities to receive major trauma patients are always by-passed by the pre-hospital system.

Trauma call activation

At the receiving hospital, there should be agreed predefined activation criteria for a trauma call.[6] These are most usually based on mechanism of injury, acute physiology, and anatomical factors. However, there is currently no agreed national consensus on the criteria used, and within units some discretion is exercised on a case-by-case basis. Activation of a Major Trauma Call before patient arrival (pre-alert) depends upon the accuracy of pre-hospital information.

The trauma team

In most institutions, the trauma team will have predetermined members. It usually comprises emergency department (ED) physicians, anaesthetists, general and orthopaedic surgeons, with some units providing a radiologist, neurosurgeon, and intensive care physician.[2] Exact membership and seniority will vary according to time of day, shift changes, other hospital activity, and so forth. The trauma team leader can come from any of the specialities, most usually from ED in England. The quality of leadership is paramount to the safe and efficient running of trauma calls.[7] Ideally the trauma team should be (pre)-alerted and attend the ED before the arrival of the patient. This provides time for introductions and briefing with respect to roles and expertise of team members, to check equipment, to share available patient information, to plan and prepare for anticipated therapeutic and diagnostic interventions.

Whilst trauma team leadership is pivotal in these high stakes, complex, and dynamic clinical situations, so too is team followership, and training should focus on both roles. Providing the desirable high-quality, consistent, trauma team training, and experience for trainees and consultants across all TU and MTCs is a significant national challenge. Historically, medical training has focused on knowledge and skills, that is, technical factors. However, in recent years, there has been increased understanding and focus on human factors and, in particular, non-technical skills. These have been described for anaesthetists by the Anaesthetic Non-Technical Skills (ANTS) system.[8] The four skill categories described (task management, team working, situation awareness, and decision-making) are all critical determinants of successful trauma resuscitation.

The anaesthetist often contributes to the trauma team in a non-leadership role, which is entirely appropriate given the very task-orientated role of airway and breathing assessment and management. However, the position at the head of the patient presents a unique overview of both the patient and situation as a whole. In addition to specialist airways skills, anaesthetists bring to the major trauma situation their skills in the recognition and management of acute physiological derangement, including haemorrhage and shock. Findings and concerns should be clearly communicated to the team leader.

The anaesthetist is often the primary clinician providing direct continuity of care through the early part of the patient's pathway in the hospital. Multiple team and place transitions can be particularly difficult, but the use of repeated briefing and review can ensure agreed clinical understanding, shared goals, and planning to optimize team resource management. Checklists can be very helpful for equipment preparation, and can also be used to enhance safety at critical interventions and at key transitions, such as transfer to computerised tomography (CT) scan, theatre, or critical care. Transfer to these different environments necessitates safe handover of care at a time when information loss and corruption is a potential hazard. Emergency checklists can also be helpful in unusual or stressful situations such as the 'non-responder'.

The factors most commonly causing clinical problems are decision-making and effective communication within and between teams. Particular attention needs to be paid to documentation of decisions and interventions.

Patient reception and resuscitation in ED

The objectives in ED are to undertake a rapid and systematic clinical assessment; to institute immediately life-saving treatment; to use information gleaned clinically and from imaging (focused assessment with sonography in trauma and CT) to decide the most appropriate patient pathway; and safe and timely patient transfer with clear forward communication.

In the ED, the trauma team receives the patient after a comprehensive, clear handover is delivered and heard by the whole team.

The importance of a handover by paramedics transferring the patient cannot be underestimated. They have knowledge of the scene, mechanism of injury, patient condition, and pre-hospital management that will affect assessment and further care. The MIST structure (M—Mechanism of injury: I—Injuries sustained or suspected: S—vital Signs at the scene and on transport: T—Treatment and response)[9] is a useful tool for handover and forward communication.

Initial assessment is managed according to Advanced Trauma Life Support (ATLS) principles with airway and cervical spine control taking priority but with management of ABC's in parallel rather than sequence.[10] Primary survey findings are clearly communicated to the team leader and documented. The one exception to the 'ABCDE' approach of ATLS is uncommon in civilian practice but can occur, particularly in the context of penetrating wounds, when exsanguinating external haemorrhage poses the most immediate threat to life and must be controlled as a priority.

Immediate haemorrhage control

This can be achieved in the limbs by direct pressure to the wound and immediate application of a pneumatic tourniquet with the tourniquet time clearly documented in indelible ink on the patient.[11] In injuries of the junction of the thigh-groin and arm-axilla it is not possible to apply a tourniquet and haemorrhage control relies on direct pressure and packing. Control of haemorrhage from this 'junctional trauma' can be very difficult as large vessels are involved and often retract from the wound site. These patients may require emergent surgical haemorrhage control in theatre.

Airway with cervical spine control

Decision-making with respect to the need, timing, and method to achieve a definitive airway can be very challenging. Clear indications for intubation include actual and impending airway compromise. However, intubation and ventilation may also facilitate safe imaging, transfer, and required interventions in the shocked patient or the very agitated patient. In the presence of multiple painful or distressing injuries, when the inevitable destination of the patient is theatre or the intensive care unit, early anaesthesia, intubation, and ventilation is humane and offers best analgesia. NICE offers guidelines in the context of brain injury.[12]

Experienced clinical assessment will help to determine the need for a definitive airway and its urgency; the risks of securing a definitive airway *vs* not doing so; and the best intubation strategy. The decision-making, planning, and preparation should be shared with the rest of the trauma team.

There is clear evidence from NAP4 that trauma intubations are more difficult: there is a higher rate of failed intubation, surgical airway, and serious complications from emergency airway management.[13] In addition to the requirement for cervical spine neutrality and premorbid or injury related patient factors, there are the additional factors of a high pressure, time-critical situation, a noisy environment, ongoing resuscitation, potentially unrehearsed team, equipment preparation, and checking.

Penetrating injuries to the neck pose considerable challenges to the anaesthetist. Both intubation and surgical access to the trachea may be difficult when bleeding into the cervical tissues causes swelling, oedema, and soft tissue distortion. An anaesthetic trainee in the trauma call setting must always be aware of the complexity of these cases, and should feel comfortable in requesting senior anaesthetic assistance and advice. The anaesthetist must clarify the skills and experience of any team member assisting them.

Rapid sequence induction (RSI) is the most commonly used technique to establish a definitive airway in the context of trauma. Drug choices should balance known risks. Rather than attempting best possible visualization of the larynx, a good enough view to pass a bougie is preferable. This minimizes the pressor response and risk of cervical spine movement. A well-fitting collar will make laryngoscopy difficult or impossible and so the neck should be protected with manual in-line immobilization during intubation.

Airway strategy (NAP4) should be agreed and shared with the rest of the team, up to and including the plan for failure. A pre-RSI checklist is useful to check set-up and verbalize plans for failure. The Difficult Airway Society guidelines for failed intubation in RSI and 'can't intubate, can't ventilate' scenarios are familiar and widely accepted,[14] but in the trauma patient, depending upon the urgency and indication for intubation, and the physiological status of the patient, the wake-up option is rarely appropriate or possible. Laryngeal mask airway placement may provide a useful temporizing measure for oxygenation, and conduit for fibreoptic and exchange catheter intubation, but the suitability of these options is again dependent on the same limiting factors. NAP4 highlighted the higher failure and complication rate associated with needle cricothyroidotomy as a rescue option. That fact and the need for definitive airway placement has changed our rescue option to surgical cricothyroidotomy with pre-RSI marking of the cricothyroid membrane, and identification of both the equipment and person to achieve the surgical airway using a standardized technique and equipment. Successful airway assessment and management depends upon a combination of expertise, equipment, and human factors. The airway strategy should be genuinely deliverable in the given situation.

Breathing

Assessment of breathing can be difficult in a noisy ED. The conscious patient may complain of respiratory difficulty, chest tightness, shortness of breath or pain. Careful clinical examination and serial arterial blood gas analysis will provide evidence of early or evolving respiratory compromise.

Emergent chest decompression is required in the presence of tension pneumothorax (a clinical diagnosis). Needle thoracentesis should be performed in the non-ventilated patient. Thoracostomy can be performed in the ventilated, anaesthetized patient. Either should be followed by chest drain insertion, performed aseptically. Deterioration of clinical signs with a chest drain *in situ* should prompt an immediate check of the drain, for displacement or obstruction. Conventional practice has been to place a chest drain in the presence of pneumothorax, but also in the presence of rib fractures without pneumothorax if the patient is to receive intermittent positive pressure ventilation (IPPV). Chest drainage may be performed pre-anaesthesia and ventilation, but may also be achieved immediately post-induction of anaesthesia. However, chest drainage is not without both early and late complications (e.g. misplacement, displacement, lung injury, bleeding, and infection). Current intensive care practice is that patients with rib fractures alone or small pneumothorax will not necessarily need chest drainage. However, in the complex and dynamic context of polytrauma, damage control resuscitation (DCR) and surgery the decision against chest drain placement should only be made by a senior and experienced team: it depends entirely on confidence that early diagnosis and access to treat a developing pneumothorax would be possible.[15]

Although chest is one of the two primary survey X-rays, a significant proportion of both rib fractures and pneumothoraces (particularly anterior) may be missed. The decision to CT scan earlier in resuscitation means that many trauma teams are foregoing the standard chest X-ray in favour of very early CT, which has a far higher diagnostic accuracy.

Clinical factors (injuries and physiology) and arterial blood gas analysis will guide the decision to provide emergent ventilatory support. Lung protective strategies should be used in the presence of IPPV, aiming for VTe of 6–8 ml kg^{-1} and $P_{max} < 30$. Normocapnia (4.5–5 kPa) is the ideal in all patients including the brain injured, with two exceptions: the first is the use of increased ventilation as a temporizing measure in the presence of impending brain stem herniation, the second is the use of permissive hypercapnia in the presence of lung injury. Both of these are senior decisions.

Circulation

Life threatening haemorrhage may be external or concealed within a body cavity. Evans and colleagues showed that 30% pre-hospital and in-hospital deaths after trauma were because of exsanguination.[16] The haemorrhage occurred from the aorta (23%), chest (23%), pelvic fracture (23%), abdomen (10%), and extremities (7%). Haemorrhage continues to be a cause of preventable death in trauma.[17]

Recognition of haemorrhage can be very challenging in the polytrauma patient because of many factors including varied individual physiology and reserve, pre-hospital treatment, comorbidity, and medications. In some patients, exsanguinating haemorrhage (e.g. pelvic fractures or penetrating trauma) results in a Bezold Jarisch reflex with no tachycardia.[18 19]

It is essential to use all available clinical information such as mechanism of injury and injury patterns, trends in physiological and metabolic parameters, changing levels of cerebration, peripheral perfusion, and urine output (once catheterized).

Much of our understanding and management of haemorrhage in trauma has benefited significantly from conflict medicine. However, the UK trauma population is of varied age and comorbidity, and the mechanism of injury is predominantly blunt. There has, for some time, been a recognition that the shocked polytrauma patient with significant tissue damage and high injury severity score, is likely to be coagulopathic at presentation because of the acute coagulopathy of trauma (ACoT). This is associated with early systemic anticoagulation and hyperfibrinolysis.[20]

The effect of ACoT will only be compounded by failure to recognize and control haemorrhage, under-resuscitation, or overzealous use of crystalloid resuscitation contributing to the 'lethal triad' of acidaemia, coagulopathy, and hypothermia. Traditional coagulation testing has several limitations in the acutely bleeding trauma patient. The tests are poor predictors of the need for massive transfusion, and have limited ability to direct early blood product therapy, due in part to time delays and the application of arbitrarily chosen laboratory triggers. For example, the usual laboratory trigger for administration of fresh frozen plasma (FFP) is a PT$>$1.5 times normal, but in trauma it has been shown that a PT ratio of $>$1.2 is associated with both increased transfusion requirements and higher mortality.[21] Point of care viscoelastic coagulation tests (thromboelastography and thromboelastometry) offer rapid information with respect to clot generation, strength and breakdown in whole blood, and may be useful for the early identification and focused management of coagulation abnormalities.[22]

All of these factors have led to the development of DCR strategies in patients with polytrauma and suspected major haemorrhage rather than the traditional high-volume resuscitation followed by definitive surgery.

Damage control resuscitation

The key components of DCR are: time limited permissive hypotension, the use of massive haemorrhage protocols and tranexamic acid, and damage control surgery (DCS). Time to surgery (or angiography) and haemorrhage control is a key determinant of outcome (mortality) and the transfer to surgery should only be delayed for key, life-saving interventions.

Time limited permissive hypotension

Time limited permissive hypotension aims to limit fluid resuscitation, thus reducing the risks of hydrostatically induced clot disruption and worsening dilutional coagulopathy, until haemorrhage control has been achieved (beyond which, definitive resuscitation is the aim). It is a balance of risks, and the chosen target pressures have been the subject of extensive discussion and some controversy, particularly in the context of the severely injured patient with both traumatic brain injury and active bleeding.[23–25]

Pre-hospital practice uses a strict fluid resuscitation protocol of 250 ml boluses of crystalloid titrated to achieve a palpable radial pulse, which estimates a systolic blood pressure of about 70 mm Hg.[26] In hospital resuscitation target pressures should acknowledge the nature of traumatic injury (which is predominantly blunt in the UK), and the complex comorbidity of our ageing trauma patient population. The key to permissive hypotension is that it must be time limited, with the earliest possible haemorrhage control, either by surgery or interventional radiology. This requires prompt recognition of the primary source of haemorrhage.

Massive transfusion protocols

Massive transfusion protocols have been developed in recognition of the fact that shocked, severely injured polytrauma patients are known to arrive coagulopathic. They facilitate the early administration of both blood and blood products to resuscitate not only volaemic status, but also oxygen carrying capacity and haemostatic capacity. Military experience in recent conflicts has shown that early administration of FFP and platelets reduces the requirement for packed red cells in those patients requiring massive transfusion and the military have moved the administration of massive transfusion protocols forward to the pre-hospital phase.[27 28]

Activation of a massive transfusion protocol should be based on predetermined criteria and require a single phone call to the blood bank technician. With excellent communication from pre-hospital medical teams, some MTCs are able to activate the protocol before the patient arrives. The exact composition of the sequential packs will be determined locally, and should be reviewed regularly in light of continual audit of patient outcome balanced against product utilization and wastage.

Hypocalcaemia is a real risk with the use of massive transfusion protocols, therefore calcium levels should be checked by regular arterial blood gas sampling and corrected as necessary. Blood products should be warmed and given rapidly.

The optimal patient management requires close communication and cooperation with the haematology service, and, if available, the rapidity of point of care testing facilitates a much more individualized treatment of patient coagulation status from the early stages of management.

Tranexamic acid

The use of this antifibrinolytic drug has demonstrated few adverse events and no increase in thromboembolic complications. The CRASH-2 study found early treatment with tranexamic acid, within 1 h from injury significantly reduced the risk of death from bleeding.[29] It is more effective in penetrating than blunt trauma but because it has a high therapeutic index, tranexamic acid should be administered early (within 3 h of injury) to all trauma victims with a systolic blood pressure $<$110 mm Hg, heart rate $>$110, or both with evidence of haemorrhage.[30] Tranexamic acid is now administered as part of pre-hospital care in many regions. The CRASH 2 study results are based on a dose of 1 g over 10 min with a further 1 g over 8 h.

Hypotension with associated pelvic fracture

Pelvic fracture can result in catastrophic haemorrhage with associated occult coagulopathy. Early splinting of pelvic fractures reduces movement and protects clot formation. The use of pelvic binders is now routine in the pre-hospital setting, with correct placement at the level of the greater trochanters decreasing the pelvic volume in open book fractures (classically caused by anteroposterior compression injuries) while still allowing access to the abdomen.[31] It is appropriate to apply a pelvic binder to any injured patient presenting with a tachycardia, hypotension, or mechanism of injury suggestive of a pelvic injury. Such is the success of a well-placed binder that the pelvic radiograph may appear normal. When clinical suspicion of pelvic injury exists a second radiograph with the binder temporarily released is necessary. Pelvic binders can remain *in situ* for up to 24 h in the majority of cases. In addition to splintage, judicious patient handling is an important part of haemorrhage control. Local policy avoids full logroll until pelvic fracture has been excluded or anatomically defined, unless the injury is because of a blast (rare in civilian practice). Pelvic fractures predominantly cause venous bleeding, but those patients with persistent hypotension have a high incidence of arterial bleeding. This may be identified on contrast CT as an arterial blush, and critically determines the best treatment to control haemorrhage. Management of these injuries will depend on local facilities (e.g. availability of interventional radiology—with the attendant issues of remote site anaesthesia in an unstable patient) and the presence or absence of intra-abdominal bleeding requiring laparotomy.

Disability

Brain injury is common in polytrauma patients, and remains a leading cause of death.[32] In the initial assessment and management phase, the aim is early recognition of a significant brain injury, which will affect chosen resuscitation targets and also the identification of a mass lesion whose treatment should be emergent surgical evacuation. The landmark papers of Seelig and Mendelow, three decades ago, showed that time to evacuation of a mass lesion is critical.[33 34]

Current NICE guidelines for the management of traumatic brain injury pertain to the indications for and timing of imaging, and also the indications for patient intubation and ventilation.[12]

The presence of brain injury implies loss of cerebral autoregulation, and, therefore the existence of pressure dependent flow with reliance on cerebral perfusion pressure. In addition, there is, in the presence of severe brain injury, a global decrease in cerebral blood flow. There is clear evidence that a single episode of hypotension more than doubles morbidity and mortality.[35] This fact dictates careful consideration of resuscitation target blood pressures and rapid haemorrhage control. The Brain Trauma Foundation recommends avoiding a systolic blood pressure of $<$90 mm Hg in traumatic brain injury.[36] The European Brain Injury Consortium and the Association of Anaesthetists of Great Britain and Ireland recommend higher targets (mean arterial blood pressures of $>$90 mm Hg and $>$80 mm Hg, respectively).[37 38] Careful consideration should be given to drug selection for RSI in the presence of brain injury and hypovolaemia in order to minimize the risk of circulatory instability. In this context, ketamine is now accepted as a suitable choice of induction agent, particularly when used in conjunction with a short-acting opioid or benzodiazepine.[39] However, the ketamine RSI does ‘look’ somewhat different and requires training in its use.

A significant proportion of these patients require transport for neurosurgical or neurointensive care. Guidelines exist for the safe transfer of brain injured patients.[38 40] Both intra- and inter-hospital transfers should adhere to the same standards.

Trauma CT

Early CT scan has become the investigation of choice for adults with severe injuries: those who do not have a CT scan have a significantly increased rate of death (OR: 0.145) and it is those that have the most severe injuries that have the most to gain from the diagnostic accuracy of early CT. The number to treat is 17: for every 17 CT scans performed in severely injured patients (ISS$>$15) there will be one additional survivor.[41] The time to CT scan after admission is an important benchmark for the quality and efficiency of the trauma team. The current trauma audit and research network audit standard is that a CT scan is performed within 30 min of arrival in the ED. Achieving this audit standard requires excellent trauma team coordination, a CT scanner co-located to the resuscitation room and a ‘hot-report’ system from the radiologist. Traditional concerns regarding the safe transfer of unstable patients to CT have changed, in part because of the close proximity of most EDs to a high-quality CT scanner, but also the speed with which a comprehensive head, neck, and trunk scan can now be acquired. One of the greatest decision-making dilemmas stems from the fact that it is often the unstable patient without an obvious primary source of haemorrhage who has most to gain from the important information provided by a CT scan, but they are also the group at greatest risk from transfer. Clear communication and decision-making involving the trauma team leader, senior anaesthetists, surgeons, and radiologists is required to balance the risk of transfer to CT with the valuable anatomical information it can provide. Should CT demonstrate a source of haemorrhage requiring emergent control, time is of the essence and, the ideal is that the patient be transferred directly to theatre or interventional radiology suite (whichever is most appropriate) rather than return to ED resus.

DCS or early total care/definitive surgery

DCS is rapid, emergency surgery to save life or limb while avoiding potentially time consuming reconstruction.[42] It has four main components

(1) Haemorrhage control.
(2) Decompression of compartments: cranium, thorax, abdomen, limbs.
(3) Decontamination of wounds and ruptured viscera.
(4) Fracture splintage.

The aim is to render the patient resuscitatable, by stopping haemorrhage, and prevent further damage whilst minimizing the surgical insult. Essential surgery is performed, followed by ‘pit stop’ resuscitation and catch-up, either in theatre or intensive care depending on local resources. This sequence may need to be repeated several times.

Early total care (ETC) is definitive fixation of all long bone fractures within 24 h of injury, but only once the patient is physiologically and metabolically normalizing and stabilizing.[43]

The decision between DCS/DCR and ETC/definitive surgery may be difficult. It should involve senior anaesthetic, surgical, and critical care clinicians, and be based on physiological and metabolic parameters.

The emergent transfer of a polytrauma patient to theatre is a time when the pre-surgical brief is at its most important. There may be multiple surgical teams involved, and hence joint planning, decision-making, and prioritization will benefit significantly from clear leadership. The briefing ensures all team members are up to date with the known injuries, physiological, metabolic, and haematological conditions of the patient. The brief also ensures that everyone is aware of the anaesthetic and surgical plans and all necessary equipment is available. This can take the form of an abbreviated 'Trauma WHO Checklist'.

Alternative surgical strategies and stop points should be identified, and shared, for default in the event of patient deterioration. Regular reviews (every 10–30 min) of physiology, metabolic and transfusion status, and surgical progress should be made and shared by the whole theatre team. It is imperative that decisions to continue with ETC as opposed to reverting to DCS are made with close communication and co-operation between the surgical and anaesthetic teams. Shared clinical understanding is essential to optimal patient care.

Tools for decision-making and targets for resuscitation

No single parameter provides an adequate integrated indicator of the adequacy of cardiac output and tissue perfusion, and therefore there is no single tool for decision-making or single target for resuscitation. Rather, a combination of physiological parameters and metabolic parameters, and their trends should form the basis for both. In the current absence of a validated integrated target or tool, the best integrator of clinical information is the experienced clinical anaesthetist.

Lactate is currently used as a surrogate indicator of the adequacy of resuscitation, but has a complex metabolism,[44] and should be interpreted in light of factors affecting that metabolism (Cohen and Woods Type A and B Lactic Acidosis) and in combination with other parameters. When coupled with acid–base estimation, resolution of acidosis is a useful marker of the adequacy of resuscitation.

Serial measurement of lactate has been described as a tool to inform the decision as to whether to implement ETC or DCS in the first 12–24 h by the Shock Trauma Centre (Baltimore, MD, USA). They have developed guidelines, based on absolute lactate levels and trends with resuscitation, to aid the decision-making process.[45] However, failure of a high lactate to settle with fluid resuscitation does not, on its own, dictate the need for further fluid resuscitation before allowing surgery, but should trigger the search for a cause and, indeed, may indicate the need for surgery to address the abnormal lactate clearance.

Another interesting, and potentially integrated, indicator of the adequacy of resuscitation is alveolar dead space. This parameter is difficult to measure in the clinical situation of trauma, but may be adequately tracked by the arterial-end tidal CO_2 difference providing other factors (e.g. ventilation strategy) remain stable. In such a situation, changes in dead space principally reflect pulmonary perfusion.[46 47]

The use of non-invasive cardiac output monitoring has intuitive benefit, however, there is little evidence to support the use of any given physiological parameter as a resuscitative target, although studies have been limited.[48] Such technologies remain controversial in intensive care practice despite >20 yr of investigation, the reasons for this are well described.[49] Clearly timing of interventions is critical, and although improved outcomes have previously been demonstrated in major surgery, the recent large multicentre optimize trial using non-invasive goal-directed fluid therapy in major surgery has shown no clear benefit. Still, its potential to guide trauma resuscitation warrants further investigation.

Single numerical haematological targets, or rather triggers, are difficult to identify given the complex and dynamic nature of traumatic injuries and the complex comorbid nature of the UK trauma population. There is conflict between the arbitrarily chosen laboratory triggers traditionally used in the non-trauma population, and current understanding regarding trauma-induced coagulopathy. The lower transfusion triggers used in the intensive care cohort reflect the fact that they may be at greater risk from the harm of transfusion (including immunological effects, respiratory compromise, etc.) with less to gain from resuscitation at a cellular level occurring sometime after the physiological insult. Thus targets derived from this cohort are not appropriate in the acute care of the trauma patient, where the balance of risks differs.

Debriefing, learning, and improvement

Care of the severely injured patient is a team game. No one person holds all of the knowledge, skills, or capacity to manage the patient completely. The early management of a major trauma case can involve many different team members over a significant period of time, and at times prove extremely challenging to any person's capabilities. Therefore, the ability to reflect and debrief within the team setting offers a fundamental opportunity to review decisions and interventions. Capturing and sharing this information is important to help systems, processes, teams, and individuals improve the quality of the performance and care they offer.

Ongoing patient care

The quality of patient rehabilitation is affected by all care from the point of injury. It is directly affected by the quality of early resuscitation and surgery. Subsequent repeated evaluation by secondary and tertiary survey is essential in order to avoid missed injuries and their consequences with timing dependent upon the patient's clinical condition and required emergent interventions. Patient management may dictate multiple returns to theatre for interval, definitive and reconstructive surgery and outcome is related to early access to rehabilitation. Early and appropriate pain management is a key component to both early care and rehabilitation and may have an important influence on the patient's long-term physical and psychological recovery.

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Declaration of interest

None declared.

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