Human factors in complex trauma

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Key points

Exemplary human factors are vital to the timely assessment and treatment of a complex trauma patient.

The designation of a trauma team leader allows a 'hands off' coordination of trauma team activity and maintenance of situational awareness.

Maintaining situational awareness allows an early reaction to changing physiology.

Communication is vital and can be facilitated by regular updates or 'sit reps'.

Followership is essential to the functioning of the complex trauma team.

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Human factors are now integrated into everyday anaesthetic practice, as a result of the work performed over a decade ago looking at anaesthetists non-technical skills (ANTS).[1] Much of this work was performed after key publications in the USA[2] and the UK[3] highlighting that human error and system design was responsible for patient harm. Subsequent high profile cases relevant to anaesthesia[4,5] have brought to light where human factors failures have led to patient death. In 2010, the Royal College of Anaesthetists dedicated the entire Anniversary Meeting to Human Factors and published a supplement to the *British Journal of Anaesthesia*. Some of the human factors related to the trauma team are listed in Table 1.

The 2007 report 'Trauma: Who Cares?'[6] highlighted the deficiencies in the delivery of trauma care in the UK, some of which resulted from failures in decision-making, communication, and team-work. Following on from this report, there has been the development of trauma centre networks around the country and a perceived improvement in trauma care delivery. The UK Defence Medical Services (UK-DMS) have attributed much of the success of their trauma care in Afghanistan to exemplary human factors,[7] particularly in the organization, briefing, and co-ordination of the trauma team.[8] This article will focus on a typical complex civilian trauma case (described in Box 1) arriving in a UK Major Trauma Centre and will demonstrate how lessons learnt by the UK-DMS are now being translated into civilian practice.

Preparing the team

Usually, there is a prehospital alert from the trauma scene and the trauma team is activated ~10 min before the estimated time of arrival. The composition of a typical UK civilian trauma team is listed in Table 2. Many NHS trauma teams are now led by a consultant (usually Emergency Physician) and will have activation criteria to ensure that the team is only mobilized when required. This is based on the mechanism of injury, anatomy, and physiology. Typical activation criteria are listed in Table 3.

By ensuring that the trauma team arrives before the patient, the trauma team leader (TTL) is given the opportunity to brief the team. This allows a projection of mental models of what the likely clinical sequence is going to be, promoting good followership. During the preparation phase, there is the opportunity to check equipment and draw up expected drugs. The anaesthesia team often has a 'wet pack' of intubation drugs,

Box 1 Clinical case

Injury at 20:10

A 25-yr-old male was cycling home in central London when he was hit by and dragged under the wheels of an articulated lorry as it was turning left. He had been cycling along on the inside of the lorry, and had gone underneath the rear axle as it turned.

He was managed on scene by two London Ambulance Service Paramedic Crews, and an ex-Helicopter Emergency Medical Service (HEMS) team paramedic. HEMS were requested but were on another mission.

The patient was not trapped, and so was pulled out from under the lorry, with 'manual in-line stabilization' *in situ* and then a cervical-spine collar, orthopaedic scoop stretcher, and pelvic binder were applied. Oxygen was administered via a 15 litre 'non-rebreather' face mask and i.v. access was obtained with 16 G cannula in the left ante-cubital fossa. One gram of tranexamic acid was given. The patient was agitated and in pain and was given 10 mg morphine i.v., before being transported to the nearest major trauma centre.

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analgesia, antibiotics, and key trauma drugs such as tranexamic acid. Contingency plans are discussed (such as dealing with a difficult airway) and telephone alerts are made to the operating theatre (OT), radiology, and transfusion.

On arrival at hospital, it is important that the handover is conducted in silence. Unless there is an impending airway problem or visible catastrophic haemorrhage then the patient should not be touched until the handover is completed. This ensures that everyone in the trauma team is aware of the handover and can start the resuscitation 'on the same page'. The UK-DMS use the acronym 'AT-MIST', standing for Age, Time of injury, Mechanism of injury, Injuries sustained, and Treatment given. This is described in Box 2 for the example patient.

Table 1 Typical human factors relevant to the trauma team

Human factor	Example
Leadership	In the trauma theatre, the anaesthetist is handed over the role of leader from the TTL. In complex trauma, there are often several surgical teams working at once and so this requires co-ordination particularly in the timings of tourniquet release
Situational awareness	The TTL should be 'hands off' as this allows them to maintain an 'all round look' (some people ask 'who is driving the bus?'). Initial information will come from the patient's handover from the paramedics, primary survey, monitoring, and initial tests such as venous blood gas
Team-working	The trauma team is a large, resource-rich unit and it is important that activity is coordinated with members performing as a team and not as individuals
Followership	Other members of the trauma team are 'followers' and must anticipate changing situations in the trauma bay. This might include preparing equipment, making phone calls to order tests or making suggestions to the team leader
Communication	There is the potential in a serious trauma for the noise levels to be raised. The TTL must ensure that noise is kept to a minimum to avoid communication failures. It is also important that observations and administered drugs are verbalized so that the team leader and scribe are aware

Table 2 Composition of a typical trauma team in an NHS major Trauma centre. ED, emergency department; ST, speciality trainee; HCA, healthcare assistant

- Trauma team leader (ED consultant)
- Primary survey doctor (ED SpR)
- Anaesthetist 1 (ST4–7)
- ODP
- Scribe (trauma nurse coordinator)
- ED nurse 1 (circulator)
- ED nurse 2 (rapid infuser)
- ED nurse 3 (rapid infuser)
- Runner (HCA)
- Orthopaedic surgeon (ST4–7)
- General surgeon (ST4–7)
- Radiographer

Table 3 Trauma team activation criteria (taken from Kings College Hospital, Major Trauma Service: Information for Members of the Trauma Team). This will apply to patients arriving at the hospital or who have a prehospital alert

1. Traumatic event and one of the following:
   - Oxygen saturation <90%
   - Systolic arterial pressure <90 mm Hg
   - Respiratory rate <9 or >29 bpm
   - GCS <14
2. Penetrating injury to
   - Head
   - Neck
   - Chest
   - Abdomen
   - Pelvis
   - All gunshot wounds
3. Fractures
   - Open or depressed skull fractures
   - Pelvic fracture
   - Two or more proximal long bone fractures
   - Flail chest
4. Traumatic amputation
5. Blast or crush injury
6. Major burns
   - 10% total body surface area but lower threshold in child or elderly
   - Combination of burns and trauma
7. Road traffic crash
   - High speed crash (>30 mph) or pedestrian *vs* vehicle at >20 mph
   - Separation of rider and bike
   - Intrusion into passenger compartment
   - Ejection from vehicle
   - Death in the same passenger compartment
   - Bull's eyed windscreen
   - 20 min extrication time
8. Falls
   - Height of >3 m
   - Paediatrics—consider the age and height of the child in relation to the height fallen
9. HEMS transfer
10. Drowning/submersion

Box 2 Handover: AT-MIST on arrival at 21:00

A 25 yr
T 20:10
M Cyclist *vs* lorry
I R-sided chest injury, abdominal distension and tenderness, and probable pelvic fracture
S Sp_{O_2} 89%, airway patient, respiratory rate 35, heart rate 130, no radial pulse present, agitated, GCS 13, moving all four limbs, in pain.
T 15 litre O_2, c-spine collar, orthopaedic scoop stretcher, pelvic binder, 16 G i.v. access in left ante-cubital fossa, 1 g tranexamic acid, 10 mg morphine i.v.

Box 3 Management in the ED. *Ketamine used as an induction agent has gained popularity for haemodynamically compromised patients. It allows a more cardiovascularly stable anaesthetic when compared with other drugs such as propofol or thiopental

- 2 units of red blood cells (RBC) given immediately via i.v. in ACF
- RSI with 1 mg kg^{-1} ketamine*, 1 μg kg^{-1} fentanyl, and 1 mg kg^{-1} rocuronium
- Immediate bilateral thoracostomies (large amount of air and some blood release on right). Intercostal chest drains sited
- Subclavian central venous line (8.5 Fr) sited on right
- RBC switched to central line, and 2 further units given
- Code Red pack A arrived from transfusion and fresh-frozen plasma started
- Second tranexamic acid dose of 1 g started as infusion
- CT scan urgently requested and transferred with Belmont Rapid Infuser (Belmont Instrument Corporation, Boston, MA, USA) running throughout.

Management in the emergency department

The initial management in the emergency department (ED) is described in Box 3.

Situational awareness and the trauma team

The complex trauma patient described in Box 1 requires a full trauma team response and the potential for the clinical condition to worsen demands exceptional situational awareness. Having a designated senior TTL allows one person, who should remain 'hands-off' the patient, to retain an overall situational awareness. One commonly accepted definition of situational awareness is 'the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future',[9] and this accurately describes how the TTL should be thinking throughout the assessment in the trauma bay. Although the TTL has overall responsibility for the team response, the anaesthetist also has an important responsibility. They must advise the TTL, provide relevant information at an appropriate time for it to be received, and assist with the decision-making process.

Damage control resuscitation

The concept of damage control resuscitation includes haemostatic resuscitation and identification of injuries and therefore the source of bleeding to achieve haemorrhage control.[10] Resuscitation to normotension is necessary after haemorrhage control in order to achieve adequate peripheral tissue perfusion. This process requires the activation of a massive transfusion protocol and communication with the transfusion laboratory. In many trauma centres, the term 'Code Red' is used to indicate a patient with major haemorrhage who requires the massive transfusion protocol to be activated. Code Red activation criteria include a systolic arterial pressure $<$90 mm Hg (at any time), patients who are non-responders to fluid boluses and suspected or confirmed haemorrhage. All EDs should have at least 2 units of red blood cells (RBC) available, but the initial massive haemorrhage protocol should also initiate 'shock packs' including clotting products. These may vary in different hospitals but are likely to contain products as in packs A and B described in Table 4. Where a HEMS team is in attendance on scene, they will declare a 'Code Red' as soon as possible to the receiving ED, and may also give prehospital red cell transfusion.

Table 4 An example of Code Red 'shock pack' contents

Pack A	Pack B
4 RBC	6 RBC
4 FFP	4 FFP
	Cryopreciptate, 1 adult therapeutic dose (2 pools of 5 units)
	Platelets, 1 adult therapeutic dose

The optimal ratio of blood product transfusion in traumatic haemorrhage is still being investigated, but the current UK-DMS massive haemorrhage protocols have been summarized recently.[11] The main aim should be to achieve identification of bleeding points and therefore source control as quickly as possible while replacing the products that are being lost. It is vital that the decision-making process around bleeding control is made swiftly and has senior input to ensure that there are no prolonged delays in treatment.

The trauma team anaesthetist

The trauma team anaesthetist must make their own assessment of the patient's physiology and injuries in order to decide on the most appropriate time to perform a rapid sequence induction (RSI) of anaesthesia and also to guide the haemostatic resuscitation. Deciding whether to go to the CT scanner, the angiography suite or the OTs next will be part of this decision-making process. This requires the anaesthetist to have good situational awareness regarding the state of the patient's physiology and the injuries that are being identified. As the trauma anaesthetist, there are a number of pitfalls that can occur

due to poor human factors in the ED phase. These are summarized in Table 5.

The patient described in Box 1 has increased respiratory effort, low oxygen saturations, and a pneumothorax on the right. He requires intubation immediately to improve oxygen delivery and to reduce the work of breathing. The patient's response to blood products must be closely observed in order to guide therapy and identify whether he is responding to the resuscitation or is still actively bleeding. The primary survey is conducted simultaneously and is coordinated by the TTL.[8] Concurrent activity is required, ideally with one anaesthetist inserting large-bore central access such as an 8.5 Fr 'trauma line' into the subclavian vein in order to rapidly infuse the blood products, while the other anaesthetist prepares to perform the RSI.

In the ideally staffed trauma team, there should be two anaesthetists for 'Code Red' patients such as this to enable one to focus on central access and blood product replacement, while the other manages the airway and ventilation. However, this is often not possible, even in many major trauma centres. As the sole trauma anaesthetist, it is easy for your 'bandwidth' (i.e. your available mental capacity) to become overloaded by a very sick patient requiring immediate multiple interventions. Recognition of this possibility and effective utilization of other team members is essential during the RSI.

Trauma patients requiring emergency intubation with simultaneous resuscitation have 'a lot going on' around them to cause distraction during the RSI. The option to wake if intubation fails, as described in the Difficult Airway Society Guidelines,[12] is not appropriate when they require ongoing resuscitation and immediate surgical intervention. Based on collective experience and published literature,[13] the UK-DMS have taken a default position of securing the airway in the majority of trauma patients requiring RSI with a Macintosh size 4 laryngoscope blade and a gum-elastic bougie with two suction devices close to hand. No more than three attempts at intubation (with re-oxygenation in between attempts) are permitted before clear communication of failed intubation with immediate progression to a surgical airway. RSI in trauma will usually require manual in-line stabilization and must be performed in a 'sterile cockpit', that is, there should be silence during the RSI to allow full concentration and identification and communication of problems.[12] The anaesthetist must allocate roles to the team as listed in Table 6, while the TTL provides situational awareness to avoid fixation errors.

Table 5 Pitfalls for the trauma anaesthetist in ED. TTL, trauma team leader; E'_{CO_2}, end-tidal carbon dioxide measurement (measured by caponography)

Pitfall	Measures to mitigate risk
Not hearing handover	Do not transfer ventilator or check tracheal tube during the prehospital handover: do it before or afterwards
Not anticipating injuries sustained	Understand the mechanism of injury and therefore potential injuries sustained
Lack of situational awareness	Understand the physiology of the patient, especially respiratory and cardiovascular status, and listen to the TTL's plans. Be aware that when your 'bandwidth' is overloaded you may not hear everything
Poor followership	Ensure that information is delivered to the TTL when they are 'ready to receive' it. Important information will not be heard or interpreted if delivered in the wrong way at the wrong time
Confusion over roles during RSI	Clearly allocate roles during preparation for RSI
Omission of important equipment during RSI (e.g. E'_{CO_2})	Use a checklist, especially if assistant is not regularly assisting at intubations
Lack of situational awareness during RSI	Use assistant and TTL as your eyes and ears during intubation. This prevents task fixation
Attempted insertion of an arterial line when the arterial pressure is very low	This does not improve the arterial pressure, it just delays surgical intervention and causes loss of situational awareness. The arterial line can be sited once the patient is on the operating table

Table 6 Team roles for RSI

Manual in-line stabilization
Cricoid pressure/laryngeal manipulation
Drug administration
Intubation

Table 7 The command huddle for critical decision-making in ED. IR, interventional radiology

Key people

ED TTL

- Provides overall leadership and situational awareness, including an understanding of the resources available

Lead surgeons (ideally general surgery and orthopaedics)

- Provide expert assessment of the injuries found, surgical options available, and priorities for surgical treatment

Lead anaesthetist

- Provides expert assessment of physiological stability, response to transfusion, and priorities for airway management

Key decisions

Treat here or transfer to another hospital?

- Does our hospital have the resources and expertise to manage this case safely?
- What are the relative risks of transferring to a specialist centre *vs* treating here?

RSI in ED or in the OT?

- How great is the risk of airway obstruction or respiratory failure before reaching the OT?
- How much safer is it to anaesthetize this patient in the OT *vs* ED?
- Will this patient be able to tolerate the move to CT/OT without anaesthesia?

CT first or straight to OT or IR?

- How much delay will be caused by getting a CT before surgery?
- Is the patient stable enough to tolerate this delay?
- How likely is it that the CT results will alter this surgery?

If straight to OT, which body cavity should be opened first?

- Where does the most time-critical injury seem to be?
- Is it possible to get proximal control of any bleeding?

If pelvic or stab wound arterial bleeding is IR more appropriate than OT?

- Is it arterial bleeding that is not likely to respond to packing?
- Is there concurrent intra-abdominal bleeding requiring laparotomy?

IR, interventional radiology.

Box 4 CT scanner information

Injuries identified on CT

- Bilateral rib fractures
- Flail chest posteriorly on right (ribs 2–8)
- Single rib fractures posteriorly on left (ribs 3–7)
- Grade 5 liver laceration, actively extravasating
- Unstable open pelvic fracture, actively extravasating

Box 5 Summary of treatment up to arrival at the OT (21:30)

Total transfusion 8 RBC and 4 FFP (with next 4 FFP *en route* to the OT from blood bank)

Anaesthesia maintained with 1% propofol infusion at 8 ml h^{-1} and midazolam boluses

AP 90/60 but only maintained while actively infusing blood products

HR 120

Weakly palpable radial pulses

Box 6 Summary of treatment up to handover in the critical care unit

OT interventions

Trauma laparotomy and packing to the liver

Retroperitoneal packing

External fixation of the pelvis

Ongoing blood product requirements despite the above procedures so progression to interventional radiology for embolization of a branch of the right internal iliac artery.

Transfer to critical care

Decision-making

The time spent in ED is important, but it is only a step towards more definitive investigations and treatment. A successful ED phase will result in the patient exiting the department quickly, with a tolerable degree of physiological stability, for timely and appropriate investigations and/or surgery.

The end of the ED phase is a time when critical decisions about further investigations, treatment, and transfer must be made. These decisions need a combined approach from at least three senior members of the team: the TTL; the lead surgeon(s); and the lead anaesthetist. In the UK-DMS, this short meeting is known as the 'Command Huddle'.[14] Key decisions that must be made at this stage are shown in Table 7. For timely and effective decisions to be made, these people must be present in person and must have sufficient seniority to make difficult decisions. Attempting to make do with junior staff in ED and telephone communication with remote consultants can only increase the risk of delayed and inappropriate care.

The patient described in Box 1 is transferred to the CT scanner and the information obtained is shown in Box 4. He is immediately transferred to the OT with a summary of treatment described in Box 5 and further interventions in Box 6.

Team working

On transfer from ED to the OT, team leadership for the resuscitation will move from the ED TTL to the lead anaesthetist. This transition of responsibility comes at a busy time for the anaesthetist and must be managed carefully to avoid errors. The safest solution is probably for the ED TTL to stay with the team and in control until the patient is safely positioned and established on the ventilator in the OT.

On arrival in the OT, it is important to ensure that the whole team are aware of the clinical situation and surgical plans. This concise update, which can be combined with the WHO Checklist, is known

Table 8 Human factors pitfalls during trauma surgery

Pitfall	Measures to mitigate risk
Unnecessary conflict over basic principles and processes (e.g. refusal of blood bank to issue sufficient quantities of blood and clotting products)	Establish clear guidelines and standard operating procedures, supported by training and multi-speciality involvement
Lack of clear leadership (e.g. three anaesthetists working together, but no defined leader with overall situational awareness)	State clearly the name of the lead anaesthetist to the whole OT team. When other anaesthetists come to help, establish defined roles for each anaesthetist
Becoming task-focused (e.g. an anaesthetist becoming fixated on inserting an arterial line or a surgeon becoming fixated on one small aspect of the surgery)	Maintain 'hands-off' leadership of the anaesthetic when sufficient assistance is available. Delegate technical tasks to other team members
Not communicating effectively (e.g. an anaesthetist and surgeon both aware of their own problems but not of each other's)	Ensure whole team is aware and prepared for critical moments including: • clamps or tourniquets going on or off • packing or mobilizing large structures (e.g. liver, lung, or heart) Use brief, regular, structured, situational reports ('sit-reps')[14] to update the team, including: • Time spent in OT • Clotting and transfusion totals • Physiological status (including temperature and acidosis) • Surgical findings, progress, and future intent

by the UK-DMS as the 'Snap Brief'.[14] The key points of information that must be communicated include:

- the main injuries found on CT and clinical examination;
- the physiological status and degree of stability;
- the transfusion given up to this point, ongoing requirements, and degree of coagulopathy (including results of near-patient testing such as RoTEM®);
- the surgical plans and expected timescale of the operation.

During trauma surgery, there are a number of human factors-related pitfalls that must be avoided. A summary of the key risks and measures that may be taken to mitigate them is shown in Table 8.

The transition to postoperative critical care is unique in the process so far, in that there is usually enough time for proper planning and handover. The opportunity should be taken to engage with the intensive care unit at the earliest opportunity. This ensures that appropriate resources can be made available and will allow a thorough handover to the receiving clinicians (ideally in the OT) for seamless continued care.

Summary

The establishment of major trauma centres around the UK has led to the concentration of trauma experience in key hospitals. Human factors such as communication, situational awareness, team working, and decision-making are all key to the timely assessment and treatment of a complex trauma patient. This article describes some of the key human factors required by the trauma team with notorious pitfalls and strategies to avoid them.

Declaration of interest

None declared.

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