British Journal of Anaesthesia **105** (1): 9–20 (2010)
doi:10.1093/bja/aeq110

BJA

REVIEW ARTICLES

Lessons from the battlefield: human factors in defence anaesthesia

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Key points

- Defence Anaesthetists deal with unfamiliar trauma very different to routine NHS practice.
- They work with different standard operating procedures (SOPs) and equipment in an unfamiliar environment.
- Human Factors are essential to ensuring success in the field hospital team.
- Pre-deployment training offers an opportunity to familiarize with equipment, SOPs and the deployed environment.

Summary. Anaesthetists in the Defence Medical Services spend most of their clinical time in the National Health Service and deploy on military operations every 6–18 months. The deployed operational environment has a number of key differences particularly as there is more severe trauma than an average UK hospital and injury patterns are mainly due to blast or ballistics. Equipment may also be unfamiliar and there is an expectation to be conversant with specific standard operating procedures. Anaesthetists must be ready to arrive and work in an established team and effective non-technical skills (or human factors) are important to ensure success. This article looks at some of the ways that the Department of Military Anaesthesia, Pain and Critical Care prepares Defence Anaesthetists to work in the deployed environment and focuses on the importance of human factors. This includes current work in the field hospital in Afghanistan and also preparing to work for the Royal Air Force and Royal Navy. We highlight the importance of human factors with reference to the type of case mix seen in the field hospital. We also detail the current pre-deployment training package, which employs multiple educational tools including high-fidelity simulation.

Keywords: education; military anaesthesia; training

The majority of Anaesthetists in the Defence Medical Services (DMS) spend most of their clinical time in the National Health Service (NHS) and deploy on military operations every 6–18 months, depending on their role. Other clinical staff are in a similar position and, despite having vast experience in civilian hospitals, will find that the deployed operational environment has a number of key differences. These need to be addressed for the individual in pre-deployment training.

The military hospital previously in Iraq and currently in Afghanistan manages much more severe trauma than an average UK hospital.[1] As a consequence, the injury patterns seen with military trauma (mainly blast and ballistic injury) are different from the blunt trauma that predominates in UK civilian practice[2–4] (the exception to this is when explosive attacks take place in the civilian environment).[5] In order to ensure best evidence practice is adhered to, Clinical Guidelines for Operations (CGOs)[6] have been devised for use in the deployed environment. Summaries of some of the pathways for ballistic, blast, and blunt trauma from CGOs are shown in Figures 1–4.

Military clinical treatment protocols may well be unfamiliar to the clinician who has not deployed before.[7] These include early and rapid use of blood and blood products within an overall construct of 'Damage Control Resuscitation' (DCR).[8 9] In addition, specialist anaesthetic and surgical equipment comes as a standardized 'module' within a field hospital. It is highly likely that this will not be the same as that used by a clinician on a daily basis in their NHS environment. In essence, the individual will face unfamiliar trauma, need to understand unfamiliar protocols, and work with unfamiliar equipment. In addition, medical units tend to change over at 3 or 6 months intervals. Within this period, individual clinicians will be 'trickle posted' in and out of the deployed unit for periods of 8–12 weeks. This means that the whole medical system needs to be prepared to work in the deployed environment and rapidly integrate individuals into the team when they arrive. Human factors play an important role in this unique clinical environment and some of those that need to be addressed in the field hospital are described with illustrative clinical cases in Tables 1–4. (These cases are not based on any particular individual but do represent the type of injuries and decisions faced by the deployed clinicians.)

Despite the above complexities, the clinical care and effect delivered on operations has recently been reviewed by the Healthcare Commission and found to be exceptional.[10] The training pathway to get the individual in tune

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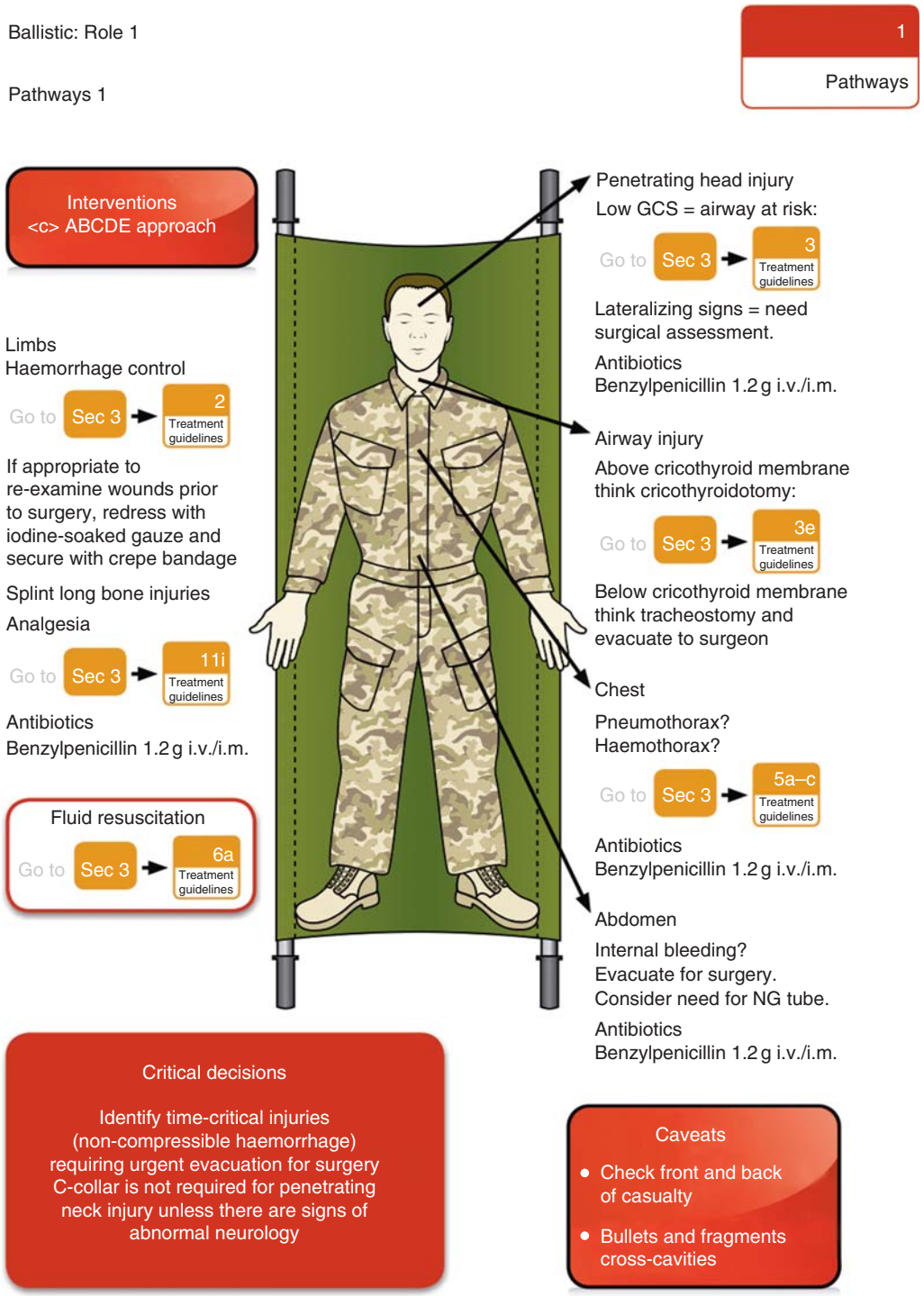

Fig 1 Ballistic trauma pathway: Role 1.

with the environment, the clinician ready for the specific casualty types, and the system ready to work in a complex environment is key to achieving this. Specific pre-deployment training courses allow individuals the opportunity to become fully immersed in their new environment and allow familiarization before arriving on operation.

Owing to the very busy schedule in the deployed environment, it is important from a human factors perspective that individuals are comfortable with the unfamiliar equipment and the environment.[11] First-rate human factors or non-technical skills (NTS) have been shown to be important in a busy operating theatre with the more effective clinician

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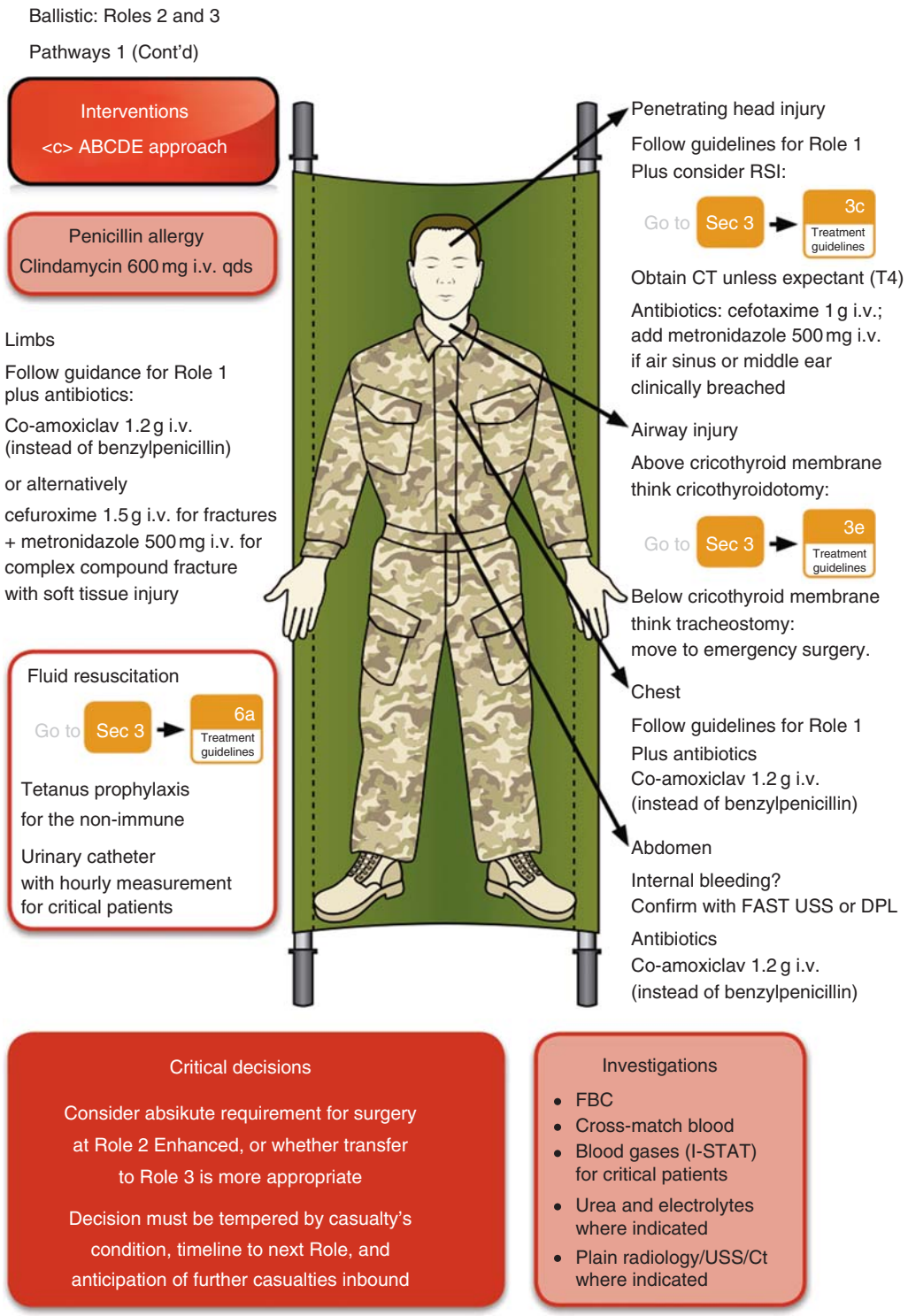

Fig 2 Ballistic trauma pathway: Roles 2 and 3.

using them well as part of their working routine.[12] In a conflict environment, an alarm bell ringing may signify the need to drop down flat on the floor ('on your belt buckle') to protect you from an incoming mortar attack. This is different from NHS where it might signify a fire alarm or the cardiac arrest bleep.

Training to prepare for the operational environment is provided at a number of levels, with the aim to provide scenarios

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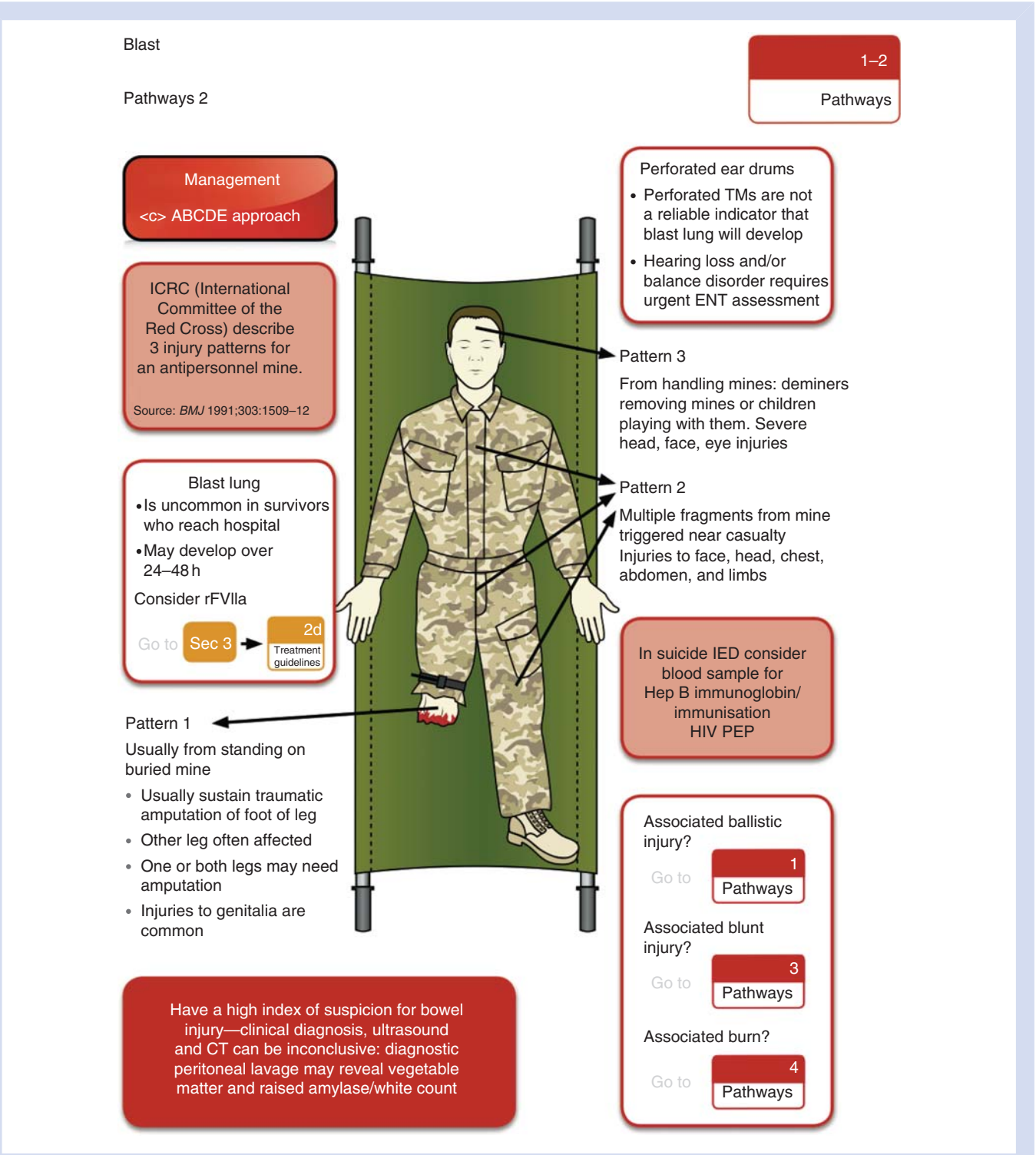

Fig 3 Blast trauma pathways.

that are as real as possible using simulation, where appropriate. Simulation allows us to deliver facilitated learning and set our own training agenda with pre-defined learning objectives and instant feedback in a safe environment.[13] The different levels of training understandably overlap and are described below.

General training: individual based

In order to ensure that individuals are up to date with the ever-changing operational environment, a service-specific intensive pre-deployment package is mandatory before deployment. It is important to realize that individuals are

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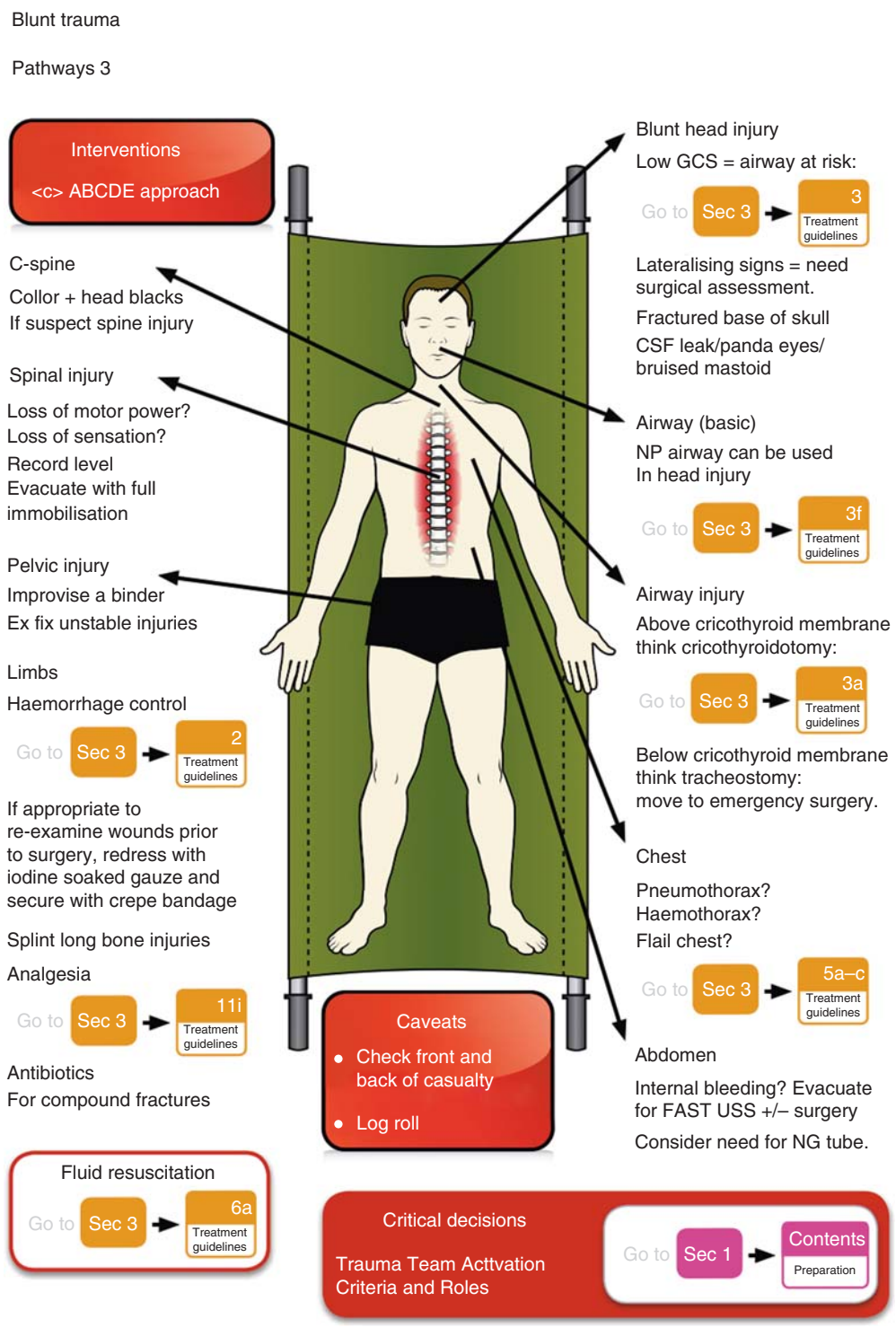

Fig 4 Blunt trauma pathways.

not only deploying as clinicians, but also as members of the armed forces and there is, in effect, no room to 'carry passengers'. Personnel have a responsibility to ensure that they are physically and mentally fit enough to work and look after themselves and their colleagues in a conflict zone. The generic pre-deployment package is summarized in Table 5.

Professional training

There are differences in the way a deployed field hospital functions compared with a typical NHS hospital. As stated above, the clinical workload is also different. To ensure that clinicians are more confident in dealing with these situations,

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Table 1 A casualty with multiple injuries

Scenario	Decisions	Key human factor elements
A 22-yr-old soldier arrives at the field hospital via the Medical Emergency Response Team (MERT).[29 30] He has been injured by an improvised explosive device (IED) and has multiple injuries	This patient will need to go to theatre in the very near future for exploration and debridement of wounds. The timing of all these procedures needs to be decided	Assemble trauma team as per hospital protocol • A balance must be reached in calling the trauma team, who may be asleep and have a busy workload the next day. There is no European Working Time Directive or shift system in place, so if people are continually woken up fatigue will result. • Reported severity of injury in the '9 liner' often does not eventually warrant a trauma team call[16]
	Should the patient remain in the emergency department or move directly into theatre?	Mobilize resources • Radiographer to prepare CT Scanner • Laboratory staff to deal with the possibility of a massive transfusion requirement All team members must be aware of their environment • Team composition (Fig. 5) • Individual roles • Equipment • Standard operating procedures Cross-check and double-check[11] • Primary and secondary survey as per BATLS[14] • Communicate findings to team Cognitive aids • Local SOPs • Clinical Guidelines for Operations[6] • Surgeon General Policy Letters Careful anticipation and planning ensure that equipment is in the correct location and is functioning Leadership change if patient is transferred to theatre

there are several professional courses that they are expected to attend in the build up to their deployment. Elements of these overlap and cover aspects of team training.

Battlefield Advanced Trauma Life Support Course[14]

This course historically takes its roots from the Advanced Trauma Life Support Course[15] and has been continuously updated to take into account best evidence and clinical experience. The most common cause of preventable death on the battlefield is external haemorrhage. This has led to the traditional ABC approach to trauma resuscitation being revisited for the ballistic environment and presented as a new paradigm: <*C*>*ABC* (where <*C*> represents the need to control catastrophic haemorrhage as the over-riding priority).[7] There are four discrete levels of care covered on the course, all of which require human factors training. This is summarized in Table 6.

There is an interactive emphasis on teaching using part-task trainers and low-fidelity manikins in addition to interactive case-based workshops. Reinforcement of the key principles such as <*C*>*ABC* and practice using the specific standard operating procedures[6] is encouraged to promote communication and teamwork during trauma moulages. Specific communication with external bodies (such as activating the transfer team) is also rehearsed using the military communication tool the '9 liner'[16] that may be unfamiliar to some course participants.

Tri-Service Anaesthetic Apparatus Simulation Course

This is a 1-day course held at Cheshire & Mersey Simulation Centre (under contract to the MoD) and concentrates on the familiarization and use of the Tri-Service Anaesthetic Apparatus (TSAA) in crisis situations. This is a piece of anaesthetic equipment that has served the military well since it was formally described in the early 1980s.[17] It is no longer available to use in the NHS as it has no *CE Mark*. Although the current field hospital in Afghanistan uses modern

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Table 2 Multiply injured patient arriving in theatre with cardiopulmonary resuscitation ongoing.
[a]'Right Turn Resuscitation'. This is a local term that reflects the layout of the hospital in Bastion. From the front entrance, a right turn takes the patient directly into the operating theatre. A left turn moves them into the emergency department.
[b]'RoTEM' stands for 'rotation thromboelastometry' and is an enhancement of classical thromboelastography

Scenario	Decisions	Human factor elements
A 24 yr old is involved in a vehicle explosion from an IED. He arrives via the Medical Emergency Response Team (MERT) and has multiple injures	Whether to proceed with a thoracotomy or manage the patient solely by rapid i.v. infusion	A common scenario in the current Military theatre environment (45 'right turn resuscitations' in the period of July–October 2009)[31] • Prior rehearsal • Acquisition of preformed mental models built up from prior experience • Continuous practice and refinement has led to much success[32] • Individuals are tuned into to their environment, knowing their roles, theatre-specific equipment and communication issues
CPR is in progress	Where to place i.v. lines as patient may have lost limbs and skin and soft tissues may be damaged by blast or thermal injury	Cognitive aids (one such SOP has recently been published)[33]
A decision has already been made so that the patient makes a 'right turn resuscitation'[a] (Fig. 6) and by-passes the emergency department turning right and straight into theatre		Early assembly of the trauma team. In addition, the anaesthetic team will have a person responsible for • Leading the team • Airway management • Intravenous catheter insertion
The trauma team is assembled in theatre		If there is a high index of suspicion that a casualty may require '*right hand turn into theatre*' equipment such as the level one rapid infuser and central line kit will be set up ready to go in both locations
The most likely reason for his severe state is hypovolaemic shock		Decisions made quickly but with discussions between the anaesthetic and the surgical team • Anaesthetist aware of the stage of the resuscitation • Surgeon focused on thoracotomy Communication with surgeons and anaesthetists is vital during damage control surgery[8] as bleeding can be due to a cause amenable to surgery or due to derangement of clotting that could be corrected as guided by the RoTEM[b] There is an element of 'crowd control' that requires effective leadership Priorities are set dynamically and the situation is constantly re-evaluated Additional communication with • Laboratory staff • Intensive care

anaesthetic machines, there are instances where anaesthetics may be required to be delivered using the TSAA such as commando or air assault deployments. Training scenarios are designed to allow candidates to get use to this piece of equipment, as familiarization is also important for effective NTS.[11] Performance of anaesthetists in dealing with emergencies has been shown to improve with this type of simulation training.[18] If this is incorporated with a focused debrief, technical skills have also been shown to improve.[19] A recent survey of UK military anaesthetists has provided evidence of general support for simulation in pre-deployment training.[20]

Field surgical team

Military Operational Surgery Course

This course takes place in the Simulation Suite at the Royal College of Surgeons and allows scenarios to be rehearsed

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Table 3 A multiply injured patient is anaesthetized in the operating theatre

Scenario	Decisions	Human factor elements
Multiply injured patient anaesthetized in the operating theatre for damage control surgery	Sequence of surgical procedures depending on the priority	Clinical situation that does not frequently occur in routine NHS practice
There may be multiple surgical teams	The time spent in theatre is limited when performing damage control surgery[34]	Pre-deployment training • Familiarization with environment • Familiarization with equipment
	Need to return to CT after thoracotomy	SOPs[6] to encourage teamwork and communication, effective leadership and followership
	Is a laparotomy required?	Leader must • Communicate with the surgical teams when to operate and when to pause depending on the patient's physiology and the stage of the resuscitation • Coordinate the anaesthetist responsible for vascular access • Coordinate the anaesthetist responsible for airway management • Coordinate OPDs running the 'level one' infusion device • Maintain situational awareness—crucial to success, as anticipation and planning for frequent changes in condition will be necessary
	The process of achieving vascular control in damaged limbs	Patient's condition and management are constantly re-evaluated in case changes need to be made to the original plan
	Decision to halt surgery to allow a period of physiological stability on ITU	Additional communication with • Laboratory • ITU—decision can be made if evacuation to Role 4 (Royal Centre for Defence Medicine) is required and the CCAST team needs to be mobilized from RAF Lyneham

Table 4 A multiply injured patient anaesthetized and receiving large-volume fluid replacement

Scenario	Decisions	Human factor elements
Multiply injured patient is anaesthetized in the operating theatre and receiving a large-volume fluid replacement	Where to site IV access (current practice is a subclavian CVP line). Will be influenced by site of injury	Ongoing experience of dealing with damage control resuscitation has allowed the practice and refinement of this process based on that experience
	Type of fluid to administer? Priority is to give blood and blood products	It is important that all members of the team are 'singing from the same hymn sheet' (working in a coordinated manner, with shared goals and common procedures)
	The rate of fluid administration?	The use of SOPs[33] to improve teamwork and communication
	The clinical parameters that are being chased	Communication • With the team controlling the 'level one infuser'—when to start • Laboratory staff • Intensive care • Hospital Management Cell (HMC)
	Monitoring and management of hyperkalaemia and hypocalcaemia	

with surgeons, anaesthetists, and operating department practitioners. It is intended to involve emergency department physicians, and other professions allied to healthcare, as the course develops to allow a truly multidisciplinary approach to patient management. Scenarios have been designed to reflect current practice in the field hospital in Afghanistan with the input of subject matter experts who have recently returned from the conflict. They concentrate on a number of important issues such as DCR[8] and burns management. The availability of the wireless manikin,

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Table 5 Generic pre-deployment package

Pre-deployment element	Key features
Operational briefings	Introduction to the environment in terms of • Climate • Language • Culture • History • Political background • Aims of the operation
Familiarization with theatre-specific equipment	Personal protective equipment (e.g. combat body armour) worn for periods of time to allow familiarity
Weapons handling test	Issue of SA-80 rifle Demonstration of safe operation, maintenance and disassembly Weapon firing test
Field craft	Additional field craft is depending on deployment
Practice in field environment	Foot patrolling Actions on ambush in a vehicle Actions on land mine discovery
Fitness test	Mandatory (parameters depend on their age and gender)

Table 6 Levels of care rehearsed on BATLS Course

Level of care	What is involved
Care under fire	Treatment is delivered in a non-permissive environment. The clinician is actually treating and evacuating their casualty while under enemy attack
Tactical field care	Treatment is delivered at the point of wounding in a permissive or semi-permissive environment This process not only introduces the very dangerous and hazardous environment, but also allows rehearsal of key non-technical skills such as leadership, communication, and team working. Other members of the team are encouraged to adopt effective followership
Field resuscitation	Care is conducted at what is essentially a field dressing station (usually denoted Role 1). Equipment issues play a strong role, as does communication with the field hospital and Medical Emergency Response Team (MERT) The team available is not necessarily all of a medical background, with chefs and gunners being required to hold fluids and act as runners to obtain equipment
Advanced resuscitation	This is team-based and consultant-directed resuscitation in a field hospital (usually denoted Role 3)

SimMan 3G® (Laerdal Medical Ltd, Orpington, UK), has allowed scenarios to begin with a warning call from the MERT *en route* with a patient to the emergency department.

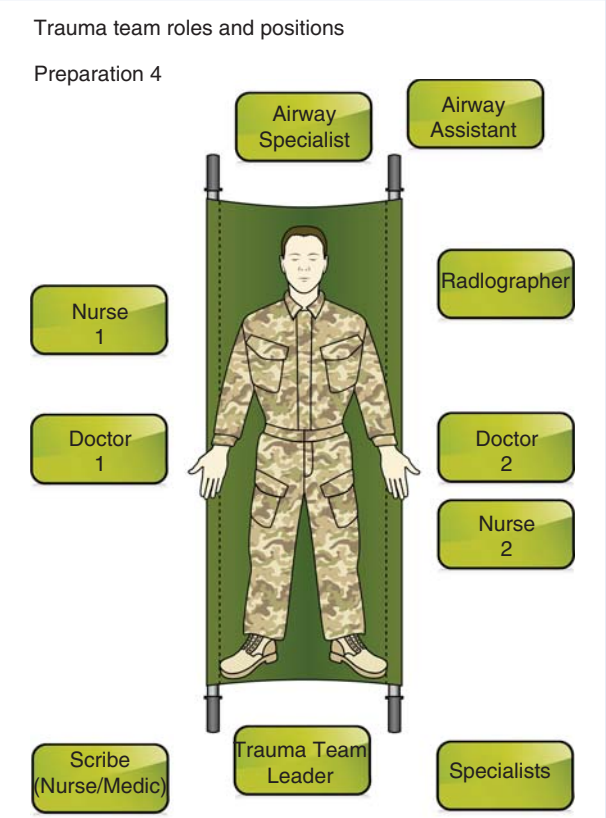

Fig 5 Trauma team roles and positions.

Simulation provides the opportunity to bridge any educational gaps, particularly for team training in DCR.[8]

This course is constantly evolving, and in order to provide the highest fidelity, efforts have been made to recreate the field hospital operating theatre or emergency department including all the equipment that would be available. This is particularly important as candidates are given the opportunity to acquaint themselves with the environment they will be working with on deployment, again key to effective NTS.[11] The manikin is also 'mocked up' depending on the injuries received including burnt military uniform (CS95-Desert), and simulated gunshot wounds. Diesel fumes in the air of the simulation suite simulate the smell of aviation fuel familiar to those who have deployed. All scenarios are video recorded and are followed by a focused debrief concentrating on correct patient management with an emphasis on human factors. An experienced faculty is present and it is important to have credible subject matter experts present to facilitate the debriefing of technical skills. Recently, a military trainee has been able to undertake a clinical fellowship in simulation in healthcare to gain experience in running such courses.[21]

The hospital exercise 'HOSPEX'

This is held at Army Medical Services Training Centre (AMSTC) near York and is in effect a macro-simulation that

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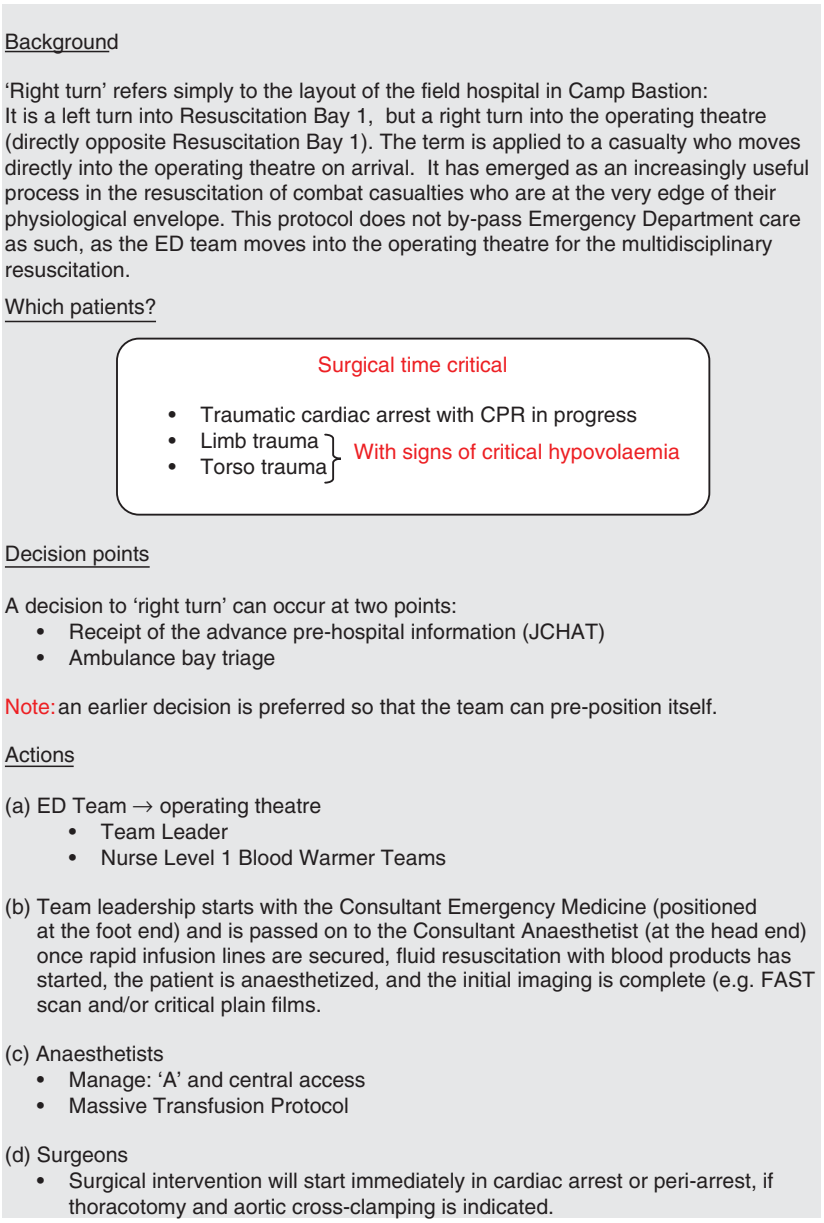

Fig 6 Right turn resuscitation.

involves the whole of the deploying field hospital.[22] An aircraft hanger has been 'mocked up' to represent the exact outline of the field hospital with all the available equipment and personnel being present. In order to provide a fully immersive experience, candidates dress in the same clothing that they will wear on deployment, including body armour, CS95 clothing, and desert boots. This exercise provides an opportunity for teams who are deploying together to practice simulated scenarios and rehearse how they would work together in the field hospital. The NHS operating theatre has been described as a highly complex environment similar to an airplane cockpit[23] and this is not different in the field hospital emergency department or theatre where human factors play an important role in patient safety and clinical outcome.

In order that HOSPEX be successful, it is important that the entire multidisciplinary team be present including administrative medical commanders. This ensures that admission and discharge processes can be tested and real-time leadership, communication, decision-making, and other crisis management skills practiced. HOSPEX uses real-life scenarios that have been devised by subject matter experts to ensure that the exercise is as realistic as possible and are constantly updated based on current operational experience. Simulation can provide an additional means to explore any potential vulnerability that exists in healthcare delivery,[24] particularly

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as all aspects of the field hospital team are exercised together.

Aviation environment

Since the mid-1990s, the RAF's 'Critical Care Air Support Team' (CCAST) aims to provide UK standard levels of critical care to ventilated patients requiring repatriation. Over the last decade, CCAST has moved 464 priority 1 and 2 critical care patients. The team is prepared to operate in extreme, unusual, tiring, and often-unpredictable circumstances for up to 48 h. Maintaining high clinical standards requires exceptional teamwork and this is achieved through a stringent training schedule.

The CCAST team is composed as a minimum of a Consultant Anaesthetist, Intensive Care Nurse, Flight Nursing Assistant, and a Medical Equipment technician. More recently, the team has been reinforced by a second Intensive Care Nurse and wherever possible, a senior anaesthetic trainee. The team spends a month on '6 hours notice to move' and by the time the CCAST first meets their patient, they may have been travelling for up to 16 h. On average, a single complete aero-medical mission can take up to 36 h from first activation.

Close interaction with the aircrew is required while simultaneously providing clinical care. This is considerably more challenging due to the environmental stressors including additional noise, vibration, changes in ambient light, temperature, pressure, humidity, and acceleration forces and these have been shown to affect human performance.[25] In addition to the difficulties of caring for a patient during flight, the CCAST team will experience disturbed biological rhythms, related to sleep disturbance as a consequence of increased speed and trans-meridian travel.

Every member of the team undergoes regular equipment training and this is refreshed on the CCAST(E) course (*Equipment*). Training starts with regular familiarization flights to allow new members to acclimatize to the aviation environment stressors before having to focus on their clinical roles. Simulated environments such as a 'Hercules Rear Crew Trainer' and 'Chinook Simulator' allow team training to take place with immediate focused human factors debrief. An understanding of the requirements of the aircrew is also essential, so that both the clinical and aviation teams can interact effectively in the decision-making processes.

Maritime environment

Deploying as an anaesthetist on a maritime platform for the Royal Navy may involve working on one of the aircraft carriers HMS Illustrious or HMS Ark Royal, which have surgical capability, an amphibious ship such as HMS Ocean or the Primary Casualty Receiving Ship (PCRS), RFA Argus. This provides the opportunity to work with a theatre team in another unique and different environment. Environmental and equipment familiarization is vital and is an ongoing process that begins on joining the Royal Navy. Doctors, regardless of their career path, undergo an intensive New Entry Medical Officers Course (NEMO Course). Not only does this introduce candidates to the military requirements to serve at sea, but also it involves a number for short courses. The initial and pre-deployment training is summarized in Table 7.

Anaesthetic trainees

Currently, operations are at a high tempo, but we must prepare to train junior anaesthetists to deploy even in times of relative peace. Recently, a military training module has been approved by the Royal College of Anaesthetists and simulation has been suggested as a means of delivering some of its components.[26] The syllabus includes leadership, communication, and team-working skills.

Table 7 Maritime initial and pre-deployment training

Combat Casualty Care Course	Based onboard a warship berthed in a training establishment. Opportunity to get to grips with basic ships knowledge in the context of treating and transferring simulated casualties. Key decision-making and leadership skills are rehearsed. Communication is important not only with the clinical team but also with the crew who are driving the ship
Fire-fighting Training	Rehearsal practicing as part of the fire-fighting team. Using real equipment
Chemical, Biological, Radiological, Nuclear and Damage (CBRN) Control Course	CBRN background. Rehearsal treating casualties with the fully protective clothing. Demonstrates the difficulties of working in this environment and the additional stresses provided by the protective clothing
Damage Repair Instructional Unit (DRIU)	Damage control simulator based at the Phoenix NBCD School at HMS Excellent. Experience flood damage in a moving ship in scenarios involving ship grounding and damage from enemy fire Candidates perform damage control tasks such as hammering wooden blocks into holes in the ship's hull in freezing cold water, with smoke and noise from flood alarms. In essence, this is the most realistic mock-up of a ship about to sink
Basic Sea Survival Course	Introduction to the process of abandoning a sinking vessel including manning a life craft and protective clothing
Helicopter Ditching Escape Training (Dunker)	Ensures familiarity with the layout out a helicopter cabin and the procedures if it were to ditch over water

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The future

Data on all major trauma casualties treated by the DMS are collected by Trauma Nurse Coordinators and returned to the Joint Theatre Trauma Registry at RCDM.[27] This is analysed for emerging injury patterns and to look for clinical issues that have been done well or could be improved upon. These lessons are used to feedback to the deployed teams at the weekly Joint Theatre Clinical Case Conference[28] (JTCCC) and into the training courses described above. Specific clinical issues may also be worked through with the Combat Casualty Care Group at DSTL Porton Down to identify areas that need urgent research. Results from this research are in turn fed back into the training and development pathway for those about to deploy.

Conflict of interest

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Funding

No funding was received for writing this article. The authors have no commercial interests to declare but are involved in the design and delivery of pre-deployment training to Defence Anaesthetists.

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