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The Management Of Head Injuries On Military Operations

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ABSTRACT

The management of head injured patients has recently been reviewed with the development of civilian guidelines for best practice. These are common injuries which often have significant sequelae for patients and costs for health care providers. Evolving civilian standards of care have implications for military medicine which is often practised in challenging environments. Considerable planning and resources are necessary to meet these standards in an operational environment. The current standards and the problems of applying them in an operational theatre are discussed

Introduction

Head injuries are a significant cause of morbidity in the general population. They are the leading cause of death and disability in children and adults in their most productive years (1). They incur a significant human and financial burden for patients and health planners. The organisation of civilian services to provide specialist head injury care is undergoing marked change to meet increased public expectations and achieve evidence based practice. Issues which have been raised in civilian practice include which specialty is best placed to undertake the initial management of those head injured patients not requiring neurosurgical expertise, the role of imaging and the time frame within which this should be available (2,3). War surgery reports have identified head injuries including traumatic brain injury as a significant cause of both morbidity and mortality in recent and historical conflicts (4-8). As in civilian practice, the overwhelming proportion of traumatic brain injury relates to blunt injuries, however, penetrating injuries must also be considered in a military environment (5,9). It is accepted that interventions in the immediate or early post injury phase can have significant implications for recovery from moderate and severe traumatic brain injury. It is important that medical personnel attending to head injured patients are well trained and aware of current management principles. This is particularly important when working in the isolated or challenging environments of military operations.

Civilian Guidelines

Head Injury guidelines have been shown to be effective where clinicians with differing levels of skill and experience provide care for casualties in varied settings (10,11). In UK practice several reports have addressed the problems of managing head injuries with varied conclusions and applicability (2,3,12). Even with the resources available in civilian practice, recommendations have been difficult to agree and implement. The Galasko report (12) recognised the variations in the skill and experience of medical practitioners responsible for the care of head injured patients. It recommended a shift in responsibility away from the surgical and orthopaedic departments to departments of emergency medicine. This report has been the subject of considerable comment and study, not least because of the significant resource implications identified for emergency medicine departments and neurosurgical units. Many of the Galasko recommendations have not been implemented (13).

The National Institute for Clinical Excellence (NICE) reports have been similarly received with particular concern over resource implications for departments of emergency medicine, radiology and neurosurgery (14,15). Computed tomography (CT) imaging is increasingly available and the threshold for this investigation has been significantly reduced under NICE guidance. The role for plain skull radiography has been diminished. Guidance from the Scottish Intercollegiate Guidelines Network (SIGN) has been used in Scotland for several years and has now come to be viewed as a practical alternative to NICE guidance (15). These difficulties can be expected to translate into military medicine.

Military Medical Support and Forward Surgery

The operational environment provides challenges not just for the severely injured but also for the monitoring of those patients who in civilian practice would be sent home with head injury advice under the observation of a responsible adult. Supervision of such

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soldiers, who may have access to live ammunition, will involve a restriction of their duties and may involve physically removing them from their normal area of duty should this pose a risk to them or others. The principles of "forward surgery" incorporate the concept of "forward fixing". Current doctrine for all specialties advocates retaining military casualties with only minor injuries in a military environment wherever possible (16), as the further rearward a soldier is evacuated to receive treatment, the less likely it is that they will make an early return to full duties (17).

Historical Provision of Military Neurosurgery

There are currently no regular service neurosurgical consultants. Military operations are, therefore, dependant on neurosurgical support from the Reserve Medical services or Role 4 (United Kingdom) hospitals. This limitation means that a practical compromise must be reached to allow the delivery of treatment by appropriately trained personnel. This has been addressed by considering the skills and competencies required at each role of medical support rather than the specific specialty input required. In civilian practice, severely head injured patients are resuscitated and triaged through a variety of services including accident and emergency medicine, general surgery, critical care and trauma and orthopaedic surgery before being directed to a specialist neurosurgical centre, thus protecting the relatively scarce neurosurgical resources (consultants, operating time, beds) (18).

The military "general" surgeon has, therefore, been required to broaden his repertoire to acquire this range of experience and skills. This has implications for the continuing medical education of military surgeons as these are skills which the general surgeon is unlikely to use in peacetime practice and which will require continual updating. Where military operations are undertaken in cooperation with other nations, shared medical assets and capabilities are often agreed. This has previously included specialist neurosurgical and radiology personnel and facilities. Head injuries on operations are, however, more usually managed without access to a neurosurgeon and occasionally without CT imaging facilities. The role of the military surgeon as a generalist has necessarily been maintained. Even where a CT scanner is available, it may be the military general surgeon who is required to interpret images and to make management decisions as to the appropriateness of surgical intervention.

In theory, a lack of CT scanning facilities should not detract from the care available on operations for traumatic brain injury and does not preclude "forward neurosurgery" (8). In practice, CT imaging is an important adjunct to the management of traumatic brain injury and provides valuable information with respect to delineating missile tracts, the anatomy of the primary injury – which may offer prognostic information and identifying brain swelling and haematoma. Where CT imaging has not been available, the management of penetrating brain injuries in particular, has on occasion been made more difficult by the development of haematoma distant from the original site of injury. These lesions are ideally treated before they become clinically significant and CT imaging is extremely useful in their identification. The incidence of such a haematoma of clinical significance has been estimated at 3-4% (6). The limitations of CT imaging are also recognised as a normal initial CT scan does not necessarily exclude intracranial hypertension.

American armed forces have been able to deploy a much greater medical capability. During Operation Desert Storm the US army deployed eight specialist neurosurgeons with five forward field hospitals. One of these hospitals had CT scanning facilities (5). Historically, the US army has deployed CT scanning facilities to other areas of operation including peace support in the Former Republics of Yugoslavia and Macedonia. UK medical services have now provided this capability in a field hospital setting on Operation Telic. The surgical treatment of traumatic brain injury is recorded from the time of the first world war. Of particular note, Colonel Harvey Cushing, the father of modern neurosurgery, was instrumental in the development of neurosurgery as a whole but in particular, he introduced early neurosurgical intervention to the US casualty clearing stations of World War I, producing a marked reduction in morbidity and mortality. This "forward" neurosurgery approach and his contributions to the science and practice of neurosurgery as a whole, have established neurosurgery as a core part of war surgery.

The data provided by Carey *et al* from the five US military hospitals in Gulf War I show that the 8 neurosurgeons treated four US soldiers and eighteen Iraqis (eight soldiers and ten civilians) in a two month period. All of the US soldiers but one had intra-cerebral fragments and these three patients also required laparotomy for multiple injuries. All of the US soldiers were evacuated to a neurosurgical facility within four hours. Evacuation times for the Iraqis could only be determined for eleven of the eighteen. Five Iraqis reached a neurosurgical facility within 24 hours while six arrived within five days of injury. Only one Iraqi died (5). Two casualties treated required specialist surgery lasting between 7 and 8 hours – a complexity out with the capabilities of the generalist surgeon.

Military personnel are increasingly protected from penetrating brain injuries in armoured personnel carriers and by wearing protective helmets. Discipline and adherence to "helmet policy" have also been noted to have improved. A changing pattern of head wound distribution has been noted with an increasing incidence of basal / inferior skull injuries. Iraqi civilians and soldiers either not wearing helmets or wearing outmoded designs were more likely to sustain these injuries and a fronto-parietal pattern of injury predominated (8).

Interventions for head injured patients

The principles underlying the management of head injuries are based on the tenet that primary brain injury is irreversible and any intervention must be to stabilise the patient and minimise secondary brain injury (19). Resuscitation based on Advanced Trauma Life Support (ATLS) principles from the pre-hospital setting and extending to definitive treatment or intensive therapy, allows for a cohesive approach to management. More complicated interventions are typically required for severely head injured patients. The two major contributors to secondary brain injury are hypotension and hypoxia (20-22), thus therapies should be targeted at maintaining optimal ventilation, oxygenation and an adequate systolic, and hence cerebral, perfusion pressure.

Airway

Patients with a severe brain injury and reduced GCS are often unable to maintain their own airway (23). There is no good evidence that associates the time from injury to relate with increased morbidity or mortality. In the United Kingdom, pre-hospital intubation is usually performed without neuromuscular blockade. This is more commonly used in the United States where helicopter evacuation is more widely available. Where pre-hospital intubation is attempted, the airway stimulation associated with laryngoscopy without rapid sequence induction has been associated with raised intra cranial pressure (22). The ATLS protocol of "airway with cervical spine control" should draw attention to the significant association between severe head injury and cervical spine injury (6-8%) (23,24).

Ventilation

Critical care interventions for the brain injured are targeted to optimise oxygenation and cerebral perfusion while avoiding hypercapnia and the associated raised intracranial pressure. The deleterious effects of even transient hypoxia are well recognised (20, 21,23,24). Pfenninger and Lindner (25) found no difference in oxygenation levels for a cohort of head injured patients irrespective of the mode of airway management adopted. Cerebral vessels are particularly sensitive to carbon dioxide partial pressures. Hypercapnia causes cerebral arterial dilatation enhancing intracranial hypertension while prolonged hypocapnia may cause cerebral arterial spasm and ischaemia. The aim should be to normalise arterial carbon dioxide levels.

Forty two head injured patients with a GCS of 8 or less and who were mechanically ventilated in a pre-hospital setting were studied by David *et al* who found that 81 per cent of these patients were hypocapnic ($PaCO_2$<30mmHg) or hypercapnic ($PaCO_2$>38mmHg) on admission. They recommended end tidal CO_2 monitoring where mechanical ventilation is adopted in a pre-hospital setting (26).

Circulation

Guidance for the management of the severely head injured patient has evolved from the concept of relative dehydration to reduce potential cerebral oedema, to current guidelines which recognise the importance of maintaining an adequate cerebral perfusion pressure. Brain Trauma Foundation guidelines (27) for the management of severe head injury recommend a minimum mean arterial blood pressure of 90mmHg to provide a minimum cerebral perfusion pressure of 60 mmHg (28).

There has been a recent move towards hypotensive resuscitation of the multiply injured casualty, especially where there is uncontrolled haemorrhage. Hypertonic resuscitation has also been advocated by some and has additional logistic benefits in pre-hospital care in terms of portability and storage. In one cohort analysis, patients treated with hypertonic saline / dextran for concurrent traumatic brain injury and hypotension from penetrating trauma had improved survival rates compared to patients treated with conventional crystalloid (28). This achieved statistical significance only for selected patients subsequently requiring surgery. Hypertonic saline / dextran has not been shown to improve neurological outcomes in survivors (29). There is no role for hypotensive resuscitation in the management of the casualty with an isolated severe head injury. Where multiple injuries are sustained, treatment follows the sequence set out under the ATLS regime. Opinion remains divided over the potential of hypertonic saline for the resuscitation of severely head injured patients. There is inadequate evidence to support the routine use of hypertonic saline / dextran for this group of patients (30) however, there are few studies of sufficient quality which address this question. Hypertonic saline may prove beneficial for selected patients but should not be used routinely for pre-hospital resuscitation, particularly as this may be undertaken by a range of practitioners with varying skill levels.

Mannitol

A study examining the role of mannitol in pre-hospital resuscitation of the severely head injured patient has not established any benefit (31). It is generally used in patients with clinical signs of trans-tentorial herniation. The associated diuretic and volume depleting effect of mannitol may be counter productive where there is no clear clinical indication for its use (32).

Surgery

Surgical procedures may be temporary or definitive. They may be for the emergency relief of raised intracranial pressure, wound exploration and debridement of brain as well as the insertion of drains and monitoring devices. Intracranial pressure monitoring has become a routine part of the trauma centre or intensive care management of the severely head injured patient. Evidence suggests that monitoring the cerebral perfusion pressure is more important than the intracranial pressure *per se* (33) as this relates to both the perfusing mean arterial pressure as well as the intracranial pressure. The placement of an intra cranial pressure monitoring device can safely be performed by general and trainee surgeons trained in this procedure (34) but more complicated neurosurgical and reconstructive procedures remain the preserve of the specialist surgeon.

Pre-hospital time

The debate continues as to whether to "scoop and run" or to "stay and play". This decision may be influenced not only by the level of injury but also by the facilities available at the receiving hospital and the estimated transfer time. Care should be taken when interpreting data from different studies particularly where these may compare patients transferred to large US trauma centres with patients transferred to smaller hospitals.

Practical Operational Points

A proposed schedule is detailed below for the medical manning and capabilities required with particular reference to the management of head injured patients at each military medical role. This schedule may not require any significant increase in the manning at each role but pays attention to the specific skills and competencies required. Developing schemes for medical training and revalidation are closely related to regularly demonstrating specific competencies and experience in order to progress in training and to continue practice. This will have implications for the training of medical practitioners for specific deployed roles and the minimum composition of surgical teams. Recommendations for the required skills, competencies and facilities are made.

Casualties

Casualties, particularly those with penetrating injuries and those with severe head injuries, may present with multiple injuries. They should be managed in accordance with BATLS guidelines and any head injuries managed as part of the general resuscitation. In the field, BATLS should take precedence, however these are guidelines to inform the decision making of the clinician and may require to be adapted. These principles are evidence based, allowing cohesive and seamless care to be provided from the pre-hospital site to the field hospital by a range of practitioners. Where CT imaging is available, this should be incorporated into BATLS as appropriate. Such variations may produce a BATLS / ATLS hybrid. This will normally be in a field hospital setting where an experienced doctor can be expected to be present. Fluid resuscitation should also be guided by BATLS principles. War casualties often present with multiple injuries and in this environment they should be resuscitated using conventional crystalloids to restore the radial pulse.

Facilities

The ability to perform X-rays should be available at Role 2. CT imaging should be available in each operational theatre, normally at Role 3 and where deployed radiologists should be co-located with the scanner to interpret the images. Role 3 units also provide intensive care facilities. Where CT is available in only one facility in an operational theatre, it is preferable to co-locate it with the neurosurgeon and intensive care unit. Adequate provision should be made for dedicated casualty evacuation resources including the replenishment of oxygen supplies at all roles of medical support including regimental aid posts. Timely evacuation from the pre-hospital scene has been shown to improve survival (23) and in certain situations it may be advisable to evacuate directly from Role 1 to Role 3 – utilising helicopters if necessary. In considering the most appropriate mode of evacuation, attention should be paid to the interventions which may be required en route and the practicality of performing them.

Communication is vital. Military medical units and ambulances at all roles should be able to "speak" to each other directly to ensure adequate warning of incoming critically ill patients. Indirect communication via non-medical units or operational rooms may increase delay and the opportunity for misinterpretation or the loss of vital clinical information. As an extension, telemedicine would then be a possibility, particularly where specialist resources are stretched although this may be more suitable for the more stable environment afforded by peace support operations rather than general warfare.

Medical Manning

Role 1

Manned by at least one BATLS-trained doctor able to establish and maintain an airway, including a definitive airway if required, provide bag valve mask (BVM) ventilation and direct initial resuscitation. They should be assisted by a number of skilled paramedics who are able to recognise life threatening illness, initiate emergency treatment and perform triage. Training should be standardised across the three services and appropriate accreditation given.

Role 2

Should include a surgical team, including an experienced anaesthetist, able to relieve raised intracranial pressure and place intra- cranial pressure monitoring devices. There should be sufficient manpower to allow another doctor/paramedic to accompany evacuated patients to Role 3. This person should have skills to establish and maintain an airway, continue ventilation and to recognise life threatening emergencies encountered en route. There should be adequate facilities and manning to temporarily hold such a casualty at role 2 before rearward evacuation to role 3.

Role 3

A surgical team should be established at Role 3 able to perform adequate cranial wound exploration and brain debridement. Where a neurosurgeon is available, they should be located here. Alternatively a general surgeon with training in these procedures should be available at Role 3. Evidence from the Israeli-Lebanese conflict suggests that this surgical debridement can be performed up to 48 hours post injury with no increase in septic complications (7). Adequate manning is required to staff the intensive care unit with whilst maintaining an ongoing operative (surgical/anaesthetic) capability.

Minor Head Injuries

Where possible, these casualties should be managed at Role 1 medical facilities. Triggers for rearward evacuation should be analogous to those requiring admission in a civilian setting. Where a period of observation is advisable, a period of restricted duties, possibly even in a role 1 medical facility may allow the casualty to be observed while maintaining the soldier in a military environment. Where this is not possible the casualty should be evacuated rearwards to the next role of medical capability.

Moderate and Severe Head Injuries

Patients with these injuries would require admission in civilian practice. They also require stabilisation and rearward evacuation in military operational practice. In addition, in line with civilian practice any patient who has not achieved a consistent GCS of 15 should not be discharged back to duty. Assessment by a military surgeon and anaesthetist at role 2 or 3 will determine the need for in-theatre interventions and further rearward evacuation. Should these patients undergo surgical intervention at role 2 or require intervention greater than neurological observation over 24 hours, they should be evacuated to a role 3 facility.

Mass Casualties

Overwhelming numbers will require the use of triage to guide the allocation of treatment and evacuation resources. Follow up studies from the Vietnam conflict demonstrated that no patient lacking clinically apparent viable brain stem function survived after rearward evacuation (8).

Conclusion

The ideal management of head injured patients is challenging in optimal situations. This is even more evident in the varied scenarios of military operations. Combining clinical expertise medical facilities and adequate evacuation assets is difficult and requires considerable effort. There is evidence that protocols improve care in these scenarios. The evidence and experience presented here should help to outline the resources and skills required to address this significant area.

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