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24.10.3 Traumatic brain injury 6043 Following resuscitation identification and treatment of life-threatening expanding intracranial lesions becomes paramount. Deterioration in conscious level, routinely assessed by serial re- cording of the Glasgow Coma Score (GCS), requires immediate ac- tion, with initial management depending on the severity of head injury. (1) Severe (GCS 3–8/15)—immediate referral to a neurosur- gical unit is required; elective intubation and ventilation may be required prior to transfer; ventilation should maintain Pco2 4.0 to 4.5 kPa, and mean arterial pressure should be kept above 90 mm Hg; a CT scan will be required. (2) Moderate (GCS 9–12/15)—an urgent CT scan followed by urgent neurosurgical referral and management as for severe head injury if this reveals an intracranial abnormality. (3) Mild (GCS 13–15)—patients with GCS 15, no history of loss of consciousness, and none of a defined list of criteria for investiga- tion, may be considered for discharge according to local head injury protocols. The availability of CT scanning at all times in centres re- ceiving patients with acute head injury, together with neurological and neurointensive care facilities, is critical for the best outcomes. Complications, prognosis, and prevention (1) Acute subdural and extradural haemaotomas—rapid detection and surgical drainage is of proven value. (2) Infection—most neuro- surgeons recommend early use of prophylactic antibiotics in pene- trating injuries. (3) Cognitive symptoms—85% of adults with severe head injuries remain disabled at one year; long-term care requires multidisciplinary support in focused programmes of rehabilitation. Even ‘mild’ injuries can lead to significant ‘postconcussional symp- toms’ including headache, dizziness, poor concentration, memory impairment, and personality change. Prevention—this is a major concern for health and safety legisla- tion, town planning and traffic laws (e.g. compulsory wearing of seat belts and crash helmets). Epidemiology Traumatic brain injury is the leading cause of death and disability in high income countries in people between the ages of 5 and 45. Epidemiological data regarding traumatic brain injury from the United States suggests that 1.7 million people seek medical help fol- lowing a head injury every year. It is estimated that there are 88/ 100 000 population hospital admissions with 5.2 million living with disability following a traumatic brain injury and 52 000 deaths per year with a total cost to society of $77 billion. In Europe there are thought to be 2.5 million traumatic brain injury sufferers per year leading to 262/100 000 population hospital admissions and approxi- mately 75 000 deaths. It is estimated that each year in the United Kingdom approxi- mately 1 million people attend hospital. Almost one-half of these are children under 16 years of age. Head injuries cause 9 deaths per 100 000 population per year in the United Kingdom. This rep- resents 1% of all deaths, but 15–20% of deaths for those aged be- tween 5 and 35 years. As mainly young people are affected, the prevalence of disability caused is very significant, with an esti- mated 135 000 people in the United Kingdom dependent on care after brain trauma. While the high mortality associated with traumatic brain injury is striking, there is increasing concern regarding long-term disability fol- lowing all severities of head injury, many of which have previously been considered mild or moderate by conventional classification systems. Traumatic brain injury severity can be classified using the Glasgow Coma Scale, a system for assessing levels of consciousness based on clinical signs such as eye opening, verbal response, and limb movement. Approximately 80–90% of all traumatic brain in- jury patients are classified as mild injury, the remainder classified as moderate or severe. The death rate for patients admitted to hospital with a moderate brain injury (GCS <13) may be as high as 30%. For those presenting with a GCS less than 8 after resuscitation the death rate may be as high as 50%. The long-term outcome of survivors of severe traumatic brain injury is poor. Only around 20% will make a good recovery when assessed using the Glasgow Outcome Score (extended) (GOSe). Basic concepts Primary and secondary injury Primary injury is the damage caused to the brain at the moment of impact. It encompasses diffuse axonal injury and focal contusions. Medicine has little to offer for primary injury; prevention, however, is a major concern for health and safety legislation, town planning, and traffic laws (such as the compulsory wearing of seat belts and crash helmets). The focus of medical intervention is the prevention of secondary damage. The pathophysiological processes involved develop over hours to days and include disturbed ionic homeostasis, excitotoxicity, cell wall and mitochondrial disruption, inflamma- tion, and derangements in oxidative metabolism. The causes of secondary brain damage can be divided into extra- cranial (e.g. hypoxia and hypotension) and intracranial (e.g. haema- toma, brain swelling, and infection). Grading the severity of injury Only 20% of patients are admitted to hospital and most of these are discharged in less than 48 h. About 1 in 500 of the patients attending hospital will develop intracranial haemorrhage. The doctor's task is to manage patients in such a way that those with preventable causes of secondary injury are identified and treated effectively. The British Society of Rehabilitation Medicine defines three broad groups depending on their Glasgow Coma Scale (GCS) score after initial resuscitation: • Mild—GCS 13 to 15 • Moderate—GCS 9 to 12 • Severe—GCS 3 to 8 This is a useful categorization for decision-making in head injury management. However, a review by the American National Institute for Neurological Disorder and Stroke suggested that 'the use of the Glasgow Coma Scale failed to reflect the heterogeneity of traumatic brain injury and consequently limited the findings of trials that used it as a classifier for patient inclusion'. It should not be confused with other schemes, which are generally retrospective and used for epi- demiological and statistical purposes.

section 24 Neurological disorders 6044 The golden hour Taking into account the practicalities of computed tomography (CT), interhospital transfer, and preparation for theatre, the time available for initial assessment, resuscitation and treatment of other injuries in the hospital emergency department is less than 1 h. This is sometimes referred to as the 'golden hour' in which rapid action is critical to the patient's outcome. In a typical series of patients who had surgery for acute subdural haematoma, over 70% had a functional recovery (good recovery or moderate disability) if the delay from injury to operation was less than 2 h. If the delay was between 2 and 4 h, just over 60% made a functional recovery. In contrast, for those whose operation was more than 4 h after the injury, less than 10% made a functional recovery (Fig. 24.10.3.1). Such observations led to the Royal College of Surgeons' guide- line stating that evacuation of haematoma, when required, should be done within 4 h. The National Institute for Health and Care Excellence (NICE) guidelines specified that CT should be per- formed and assessed within 1 h of the initial request, when indicated. Despite this consensus for rapid assessment and intervention, the realities of resources and interhospital transfer still make this diffi- cult to achieve. Patients who 'talk and die'—the importance of deteriorating conscious level A classic paper, by Jennett and his team, coined the phrase 'talk and die' to describe patients whose primary injury was mild, but who succumbed to secondary injury—usually an intracranial haema- toma. Deterioration in conscious level is an urgent clinical sign that requires immediate action. The GCS (Table 24.10.3.1) is now widely used in the United Kingdom and elsewhere, giving objective recording of conscious level, with a high correlation between different observers. Any de- terioration is thus more likely to be noticed. When communicating about a patient with head injury, it is good practice to specify ob- servations of each parameter, rather than to use the corresponding numerical scores, which are open to misinterpretation, for ex- ample, a patient scoring 12 based on scores of 4 on eye opening, 3 on verbal response, and 5 on motor response should be communi- cated as E4, V3, M5. The overall sum should be given and should specify the denominator, to avoid confusion (e.g. 12/15). The most significant parameter in most cases is the motor score. Changes in motor score of even 1 point can reliably indicate that the patient has deteriorated. Change in consciousness level is the most useful clinical sign in head injury assessment. Generally, a patient with primary brain injury shows a gradually improving conscious level. A pa- tient whose conscious level deteriorates is very likely to have a secondary brain injury and, therefore, requires further in- vestigation and treatment.

Conscious level must, therefore, be assessed at the earliest opportunity, and then reassessed at fre- quent intervals. Early management of the patient with a head injury Extracranial injuries Life-threatening extracranial injuries always take priority over the head injury. However severe the head trauma, the patient needs to be stabilized for safe transfer. In addition, hypotension and hypoxia are important causes of secondary brain injury. Time-consuming de- finitive surgery such as the internal fixation of limb fractures should, however, be postponed if possible. Airway, breathing, and circulation are the first priorities. Management should follow the general recommendations taught in the Advanced Trauma Life Support (ATLS) courses. In particular, assessment should include consideration of respiratory problems, shock, and possible internal injuries. All patients with head injury should also be assumed to have a cervical spine injury until proven otherwise. Cervical immobiliza- tion should be established, unless the patient is fully conscious, co- operative, and able to convince the examining doctor that he or she has no neck pain or tenderness, a full range of cervical movement, and no neurological deficit. There are rare exceptions to this guide- line, for example, a patient with a fixed flexion deformity due to an- kylosing spondylitis might present with a cervical fracture; in that circumstance placing the neck in a ‘neutral’ position, in a cervical collar, might actually produce neurological injury. Fig. 24.10.3.1 Typical CT appearances of acute subdural haematoma. Fresh haemorrhage appears hyperdense (white). A subdural haemorrhage conforms to the surface of the brain, typically in a thin crescent. There is effacement of the lateral ventricle on the side of haematoma and midline shift away from it. An extradural haematoma, in contrast, usually appears biconvex, with well-defined edges because it is confined between the bone and dura.

24.10.3 Traumatic brain injury 6045 Initial management of head injuries After initial assessment, resuscitation, and stabilization of extracra- nial injuries, the patient is graded for the severity of the head injury. These categories then give a useful broad guide to management. Severe All patients with severe traumatic brain injury (GCS 3–8) should be discussed with the neurosurgical unit and managed in the neuro- science centre. Intubation and ventilation is necessary to maintain oxygen saturations greater than 95%, Pco2 in the range 4.0 to 4.5 kPa, and the Po2 at more than 12 kPa. At this stage, the intracranial pres- sure is unknown, but should be assumed to be high; therefore, a mean arterial pressure of at least 90 mm Hg should be maintained. One episode of hypotension (systolic <90 mm Hg), in severe trau- matic brain injury, can lead to a 50% increase in mortality. Hypoxia can also have a profound detrimental impact, although not as sig- nificant as hypotension. The main purpose of a CT scan in trauma is to identify a lesion that requires urgent neurosurgical evacuation. Indications for scan are clearly outlined in the NICE guidelines. If the guidelines are followed it should be expected that a relatively high proportion of patients attending the hospital emergency department with a head injury will require a CT scan. In most of those cases the scan will need to be done within 1 h. Mannitol and hypertonic saline can be used to treat intracranial hypertension if there is clinical evidence of life-threatening raised intracranial pressure. However, this is not a definitive treatment and should be used while the patient is rapidly prepared for transfer to the neurosurgical unit. Moderate If the head injury was moderate (GCS 9–12), an urgent CT scan would be advisable. If the CT scan detects an intracranial ab- normality, urgent neurosurgical referral is appropriate and the immediate management is similar to that for severe head injuries given here earlier. If no abnormalities are detected on a CT, care should be taken to exclude metabolic and other causes of reduced conscious level (such as hypoglycaemia or drug overdose). If it ap- pears that diffuse brain injury is the only cause of depressed con- scious level, the care of the patient is discussed with the neurosurgical unit. Moderate traumatic brain injury patients may also need to be managed in a neuroscience unit as they are at risk of secondary brain injury and may require specialist neuroscience care. Mild Most head injuries are mild (GCS 13–15). After initial assessment, the next decision is whether further investigation is required. Patients who have a GCS of 15, no history of loss of conscious- ness, and none of the criteria for investigation may be considered for discharge according to the local head injury protocol. They must be under the supervision of a responsible adult and written informa- tion must be provided concerning symptoms and signs that would warrant seeking further urgent medical advice. In this context, the criteria for CT scan include: • GCS less than 13 at any point since the injury • GCS less than 15 at 2 h after the injury • Suspected open or depressed skull fracture • Any sign of skull base fracture (‘panda eye’ periorbital bruising, cerebrospinal fluid flowing from nose or ear, Battle’s sign, haemotympanum, subconjunctival haemorrhage with no pos- terior limit) • Post-traumatic seizure • Focal neurological deficit • More than one episode of vomiting • Amnesia for more than 30 min of events before the impact If there has been any loss of consciousness or amnesia, a CT scan should also be immediately requested in patients with any of the fol- lowing risk factors: • Age 65 or older • High-energy mechanism of injury, such as a pedestrian hit by a vehicle, an occupant ejected from a vehicle, or a fall from a height greater than 1 m (about five stairs) • Anticoagulation or known coagulopathy • Significant maxillofacial injuries • Difficulty in assessment, whether due to extremes of age (very young or very old) or intoxication The validated adult rules on imaging of the head may also be safely used in children and infants, but additional criteria include: • Fall from a height greater than the height of the child • Tense fontanelle • Any suspicion of nonaccidental injury. If nonaccidental injury is suspected in a child then a skull radiograph (as part of a skeletal survey) is also useful, together with other examination such as ophthalmology for retinal haemorrhage If the CT scan shows no abnormality, the patient should be ad- mitted for observation until the consciousness level has returned to normal. Even in those patients with a GCS of 15, they should Table 24.10.3.1 The Glasgow Coma Scale Motor function Obeying commands 6 Localizing 5 Flexion 4 Abnormal flexion 3 Extension 2 None 1 Verbal response Oriented 5 Confused 4 Inappropriate words 3 Incomprehensible 2 None 1 Eye opening Spontaneous 4 To speech 3 To pain 2 None 1

section 24 Neurological disorders 6046 be admitted if there are other sources of concern to the clinician such as persistent vomiting, severe headache, drug or alcohol in- toxication, other injuries, shock, suspected nonaccidental injury, meningism, or leak of cerebrospinal fluid. If the CT scan does show an intracranial abnormality, the care of the patient should be dis- cussed with the neurosurgical unit. In most cases, transfer to the neurosurgical unit is advised. Management of intracranial complications Intracranial haematoma In almost all cases of intracranial haematoma, urgent evacuation is indicated, bearing in mind that, the longer the delay, the greater the risk of death or disability. The aforementioned guidelines for CT scan/transfer to neurosurgical unit are all aimed at the earliest diagnosis of the minority of patients with an intracranial haematoma. The risk of a traumatic intracranial haematoma depends on consciousness level and whether a skull fracture is present (Table 24.10.3.2), although the decision to proceed with CT is no longer based on initial skull radiograph, but instead on the clinical features as specified in the NICE guidelines. Even in patients with diffuse brain swelling, rather than an intra- cranial haematoma, neurosurgical intervention may be indicated. Intracranial pressure (ICP) monitoring can be useful in guiding therapy, such as judicious use of inotropes to maintain the cere- bral perfusion pressure. In patients who have persistently raised ICP despite optimization of medical management, a decompressive craniectomy can be considered. This intervention has been the subject of

multicentre randomized trials. Infection Meningitis and brain abscess can develop after any head injury in which a communication has been made between the environment and the intracranial contents. The most obvious example is a com- pound depressed fracture, where comminuted bone fragments have been forced inwards, breaching the dura. With some penetrating in- juries (such as a fall on to a sharp object or assault with a pointed weapon) the visible wound may be small and appear insignificant. As the injury may have been low velocity, the patient may have a de- ceptively normal consciousness level. Such patients should always be referred for neurosurgical assessment. CSF rhinorrhoea or otorrhoea indicates that a skull base fracture has breached the dura. This places the patient at risk of meningitis while the cerebrospinal fluid leak continues. Ninety per cent of such cases close spontaneously within 2 weeks, and usually neurosurgical intervention is not considered until this time has elapsed. An excep- tion is a fracture of the posterior wall of the frontal sinus, visualized on a CT scan. Such cases should be discussed with the neurosurgeon or the craniofacial team (if one exists locally) with a view to possible early anterior fossa repair. The use of antibiotics in cerebrospinal fluid leaks is controversial, but a working party reviewing the literature concluded that the avail- able evidence does not support the use of prophylactic antibiotics in patients with cerebrospinal fluid fistulas. Most neurosurgeons do, however, recommend early use of prophylactic antibiotics in penetrating injuries, and there is some evidence for their use in that context. Follow-up and late complications of head injury Cognitive symptoms After head injury there is a variable period before memory function returns and ongoing memories again begin to be stored. This period is referred to as post-traumatic amnesia and is a useful measure of the severity of brain damage, for example, when questioned after re- covery, a patient may not remember the accident but clearly recall being placed on a stretcher and taken into the ambulance: this would suggest a relatively short post-traumatic amnesia of a few minutes. The post-traumatic amnesia is fixed for a given injury and memories of this period do not later ‘recover’. It is also common for a patient to lose memory of events immedi- ately before the injury. This is known as retrograde amnesia. Unlike post-traumatic amnesia, the period of retrograde amnesia often pro- gressively reduces as the patient recovers. Incomplete recovery after a head injury has behavioural, cogni- tive, emotional, social, and economic effects. For adults with severe head injuries, 85% remained disabled at 1 year following the acci- dent. In the intermediate group, 63% remained disabled at 1 year. Even those with so-called ‘minor’ injuries can face considerable problems: at 3-month follow-up 79% still have headaches, 59% have symptomatic memory impairment, and 34% have not returned to work. In view of this ongoing impairment, patients who have been admitted for more than 48 h following a head injury should be re- ferred for neuroscience involvement in their follow-up. The most widely used measure of outcome after head injury is the Glasgow Outcome Scale (Table 24.10.3.3). These are broad Table 24.10.3.2 The risk of intracranial haematoma Risk factor Risk of haematoma No skull fracture Oriented 1:5983 Not oriented 1:121 Skull fracture Oriented 1:32 Not oriented 1:4 A closed depressed fracture does not require surgery except for cosmetic reasons if it is on a visible part of the skull. Table 24.10.3.3 The Glasgow Outcome Scale Good recovery Able to resume preinjury lifestyle Moderate disability Independent, but unable to resume full preinjury activities Severe disability Dependent on the care of others for the activities
of daily living Vegetative No sign of psychologically mediated responses Dead

 categories, which miss the subtleties of impairment in many who have had mild injuries. The Extended GOS (GOSE) provides more detailed categorization into eight categories by subdividing the categories of severe disability, moderate disability, and good re- covery into a lower and upper category. Its wide adoption and recognition make the Glasgow

Outcome Scale invaluable for statistical comparisons. Even ‘mild’ injuries, with early brief loss of consciousness and an initial GCS of 14 to 15, can lead to significant symp- toms that can interfere with return to previous activities. These ‘postconcussional symptoms’ include headache, dizziness, poor concentration, memory impairment, and personality change. The patient’s relatives often report personality changes, such as ‘bad temper’ and lack of motivation. Such symptoms usually improve over six months, especially if the patient and family are warned to expect such problems and reassured that they are eventually likely to resolve. Rehabilitation after severe head injury requires multidiscip- linary input from rehabilitation neurology, physiotherapy, occupa- tional therapy, speech and language therapy, and neuropsychology. Other specialists and therapy services are accessed as appropriate for each individual patient. At least as far as the Glasgow Outcome Scale is concerned, 60% of patients reach their final outcome category by 3 months after the injury. Ninety per cent (90%) reach their final score by the end of 6 months. Seizures The probability of seizures within 5 years of a traumatic brain in- jury, according to the severity, is 0.7% in patients suffering a mild injury, 1.2% in those with moderate injuries, and 10.0% in the severe group. The probability increases over 30 years to 2.1% for those with mild injuries, 4.2% for moderate and 16.7% for severe injury. Seizures are more common if there has been an intracranial haematoma, a depressed skull fracture, or post-traumatic amnesia of more than 24 h. A single seizure, within 1 week of the injury, is of less significance than repeated seizures or those occurring after the first week. Any patient who has had a seizure, craniotomy, or depressed skull fracture should be advised not to drive or operate dangerous machinery. They should also contact the Driver and Vehicle Licensing Authority (DVLA). Chronic subdural haematoma Chronic subdural haematoma is a very different condition to acute subdural haematoma in terms of pathophysiology, treatment, and patient demographics. The initial injury may have seemed very minor and may have occurred many weeks previously. The most common symptom is headache, progressively worsening and even- tually accompanied by vomiting. There may also be a focal deficit, which can vary in severity. Increasing intracranial pressure may lead to cognitive impairment and eventually a depressed level of consciousness. In contrast to traumatic brain injury described so far, chronic subdural haematomas tend to occur in an older people with a degree of cerebral atrophy, and are often associated with anticoagulant use. Whatever the pathophysiology, the treatment of choice is evacuation of the subdural collection, usually via burr holes, and irrigation of the subdural space with isotonic saline at body tem- perature. This is a relatively small operation, which can, if neces- sary, be performed under local anaesthetic, so even advanced age and general frailty do not contraindicate its use. Hydrocephalus Hydrocephalus occasionally occurs after head injury, particu- larly if there has been traumatic subarachnoid or intraventricular haemorrhage. It can be distinguished from post-traumatic cerebral atrophy by the appearances on the CT scan: in hydro- cephalus, the sulci will be small or effaced relative to the large ventricles and there may be periventricular lucency due to inter- stitial oedema. FURTHER READING American College of Surgeons Committee on Trauma (1997). Advanced trauma life-support for doctors. Student course manual, 6th edition. American College of Surgeons, Chicago, IL. 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