

NEUROLOGICAL MANAGEMENT

Head injury

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The problems posed by head injuries are vast, varied, and vexed. One million patients attend hospital in the United Kingdom every year; they present a wide range of types and severities of injury and sequelae; and there is much controversy, particularly between different specialties, about the appropriate procedures for management from acute to late stages. Head injuries are a major health problem because of their peak occurrence in young adult men; they account for many years of potential loss of life up to the age of 65 years, and for many people with lifelong disability. There are estimated to be as many people neurologically disabled due to head injury as due to stroke. No single approach to management can cater for the needs of all patients and their families, but a reasonable, rational approach follows from a consideration of the nature of head injuries and their consequences, of the scale of the problem, of the methods of treatment, and of the personnel and facilities available.

Definition

A practical operational definition, used in surveys in Scotland, incorporates a definite history of a blow to the head, a laceration of the scalp or head, or altered consciousness no matter how brief.¹ Unfortunately, in the International Classification of Diseases, there is no single code for head injury, which is covered by up to 10 rubrics that are not mutually exclusive and that are related to pathological rather than clinical features. This has greatly limited the collection of reliable statistics, except as part of special surveys, but the 10th edition does include an assessment of the duration of unconsciousness.

Epidemiology

The best guide to the incidence of head injury is the number of patients presenting to a hospital after injury; in Scotland 1976 per 100 000 per year,² in the United Kingdom a total of nearly one million per year.³ Almost half of these are children less than 15 years old and males outnumber females by more than two to one. Most injuries are due to a fall (41%), followed by an assault (20%); the importance of road traffic accidents increases with the severity of injury, they cause only

13% in those attending hospital but account for a third of patients transferred to neurosurgery and 58% of deaths. Less than one adult in five and less than one child in 10 is admitted to hospital, an overall rate in Scotland of 313 per 100 000 per year.¹ For all ages, the death rate from head injury in the United Kingdom is nine per 100 000 per year; this accounts for 1% of all deaths but for 15%-20% between the ages of 5 and 35. Death rates from head injury are already declining in road users as a reflection of existing preventive measures and further reductions should follow the increasing use of air bags.

Traumatic brain damage

Brain damage after head injury can be classified by pattern and by time course. The patterns of damage recognised by pathologists and, increasingly by imaging in life, are essentially separated into focal and diffuse varieties (table 1). It must be accepted that in many patients the most accurate description may be of a multifocal distribution—for example, multiple cortical contusions or multiple ischaemic lesions. In the time course, the differentiation is between primary damage—developing at the moment of impact—and secondary damage, due to the subsequent complications, which may be intracranial or systemic insults (table 2). Classification can also be based on mechanisms of injury—for example, missile *v* non-missile—and on whether or not there is a compound fracture, and an open or closed injury.

Diffuse axonal injury—is the single most important lesion in traumatic brain damage.⁴ It is thought to be responsible for the extent

Table 1 Lesions causing focal and diffuse patterns of damage after head injury

Focal	Diffuse
Contusion	Axonal injury
Haematoma:	Hypoxia/ischaemia
Extradural	
Subdural	
Intracerebral	
Swelling	Diffuse vascular
Infarct	Fat embolism
Pressure necrosis	Subarachnoid
haemorrhage	
Abscess	Meningitis

Table 2 Complications after head injury that cause secondary results to the damaged brain

Intracranial	Systemic
Haematoma	Hypoxia
Swelling	Hypercarbia
Raised intracranial pressure	Hypotension
Vasospasm	Severe hypocarbia
Infection	Fever
Epilepsy	Anaemia
Hydrocephalus	Hyponatraemia

of the impairment of consciousness in the acute stage and to account for much of the disability experienced by survivors in the later stages after all types of injury.⁵ It consists of scattered damage and division of axons throughout the white matter of the brain. Injury to individual axons can be recognised only by microscopy on fatal cases—silver stains show “retraction balls”, which represent swollen blobs of axoplasm. These lesions are distributed centripetally and with increasing injury extend from the subcortical white matter into the centrum semiovale, internal capsule, and brain stem. In more severe cases, they are accompanied by haemorrhage from small macroscopic tissue tears. These are located typically in the parasagittal subcortical white matter—previously called a gliding contusion—the corpus callosum, the superior cerebellar peduncle, and the dorso-lateral aspect of the brain stem. These lesions can be recognised on the cut surface of the brain in fatal cases, and are now being detected in many patients in life by CT or MRI.^{6,7}

Ischaemic brain damage is by far the most common secondary insult⁸ and is still found in more than 80% of fatal cases, despite modern intensive management.⁹ The frequency of ischaemic damage is contributed to by impairment, as a consequence of injury, of the normal regulating mechanisms by which cerebral vascular responses maintain an adequate supply of oxygen.^{10,11} The frequency of secondary ischaemic insults, particularly in patients with other injuries, has been highlighted by recent findings made with analysis of continuous monitoring.¹²⁻¹⁴ In a series of patients with varying severity of head injury, 92% were found to have one or more insults lasting for at least five minutes, despite being in a well equipped and staffed intensive care unit.

Primary and secondary traumatic brain damage are becoming less easy to separate. Thus it is recognised that axonal injury, once thought to occur at the moment of impact and be irreversible, may in fact evolve from a partial injury, in continuity, to complete disruption over some hours.¹⁵ The sequence includes unfolding of the axolemma, loss of membrane properties, damage to the cytoskeleton, and interruption of axoplasmic flow leading to local swelling and then disruption. Also, secondary damage from insults such as hypoxia may occur within minutes, before even paramedical roadside attention, and merge with the damage resulting from the

biomechanical forces acting at the moment of injury. Nevertheless, the distinction is still a useful clinical concept and underlines the importance of focusing management on the avoidance or reversal of secondary events.

Clinically the processes of primary and secondary damage are reflected in three principle patterns of evolution, each with implications for management: (1) The patient loses consciousness or develops other neurological features at the time of injury, but improves as time passes; this correlates with damage that is principally primary from which natural recovery is taking place. (2) The patient does not lose consciousness at the moment of injury but then deteriorates, or having lost consciousness then begins to worsen; each of these signals the development of secondary damage and demands immediate action. (3) Features of brain damage develop at the moment of or soon after injury and persist without change: such a patient may go on to show natural recovery but also is at increased risk of secondary complications.

Many of the issues in early treatment of head injuries concern the appropriate approach to investigation and management of these cases. The issues facing the clinician, therefore, are how severely is the patient already injured, and what are the risks of future deterioration and increased damage?

Classification: severity

Much of the confusion, scientific, clinical, as well as medicolegal, that clouds discussion and fuels controversy about head injuries can be traced to variations and discrepancies between different approaches to classification of severity of injuries. It is, therefore, important to discuss the purposes of classification and the approaches that are used; clarification of the confusion and the adoption generally of a coherent consistent approach should lead to more fruitful discussion and agreement.

The first purpose of classification of severity is in management in the acute stage: the critical factors are the patient's condition on arrival at hospital, how this is evolving, and what complications can be expected. The second is the potential for recovery, after initial assessment and acute management have been completed—when the ongoing assessment of the depth and duration of neurological impairment is of primary interest. The third concerns the inter-relation between the injury and late sequelae—here the total quantum of injury is important, both initial and due to subsequent complications; and early severity is often assessed retrospectively—for example, by duration of amnesia; this is particularly relevant to medicolegal issues. The difference in perceptions between those who have seen the patient at the acute stage—accident and emergency consultants, general and orthopaedic surgeons, neurosurgeons—and those who usually become involved only later in the assessment of sequelae—neurologists, psychologists, and psychiatrists—reflect these varying standpoints.

Table 3 Glasgow coma scale, coma score, and modifications for children under five years old

In adults (score in normal adults is 15)		
Eye opening response:		
Spontaneously		4
To speech		3
To pain		2
None		1
Best motor response (in arms):		
Obeys commands		6
Localisation to painful stimuli		5
Normal flexion to painful stimuli		4
Spastic flexion to painful stimuli		3
Extension to painful stimuli		2
None		1
Best verbal response:		
Oriented		5
Confused		4
Inappropriate words		3
Incomprehensible sounds		2
None		1
Modifications of normal response in children under 5		
Age	Best motor response	Best verbal response
<6 months	Flexion	Smiles and cries
6-12 months	Localisation	Smiles and cries
1-2 years	Localisation	Sounds and words
2-5 years	Obeys commands	Words and phrases

COMA, CONCUSSION, AMNESIA

Changes in consciousness provide the basis of most approaches to the classification of severity¹⁶; this reflects the importance of diffuse axonal injury in the initial events and in causing later sequelae. The Glasgow coma scale (table 3) separately assesses eye, verbal, and motor performance.¹⁷ This separation, appropriate conceptually because each may change independently, and very convenient in practice, may have contributed to the wide acceptance of the Glasgow approach. The temptation, however, to summate the scores of the different components into an overall coma score ranging from 3-15 could not be resisted^{18 19} and the total "coma score" now provides the most widely used basis for classification (table 4).²⁰ Nevertheless, its use needs critical review and some redefinition may be necessary, particularly in less severe injuries,²¹ even if this is at the price of some initial controversy.

The most widely used definition for severe head injury is now a patient with a Glasgow coma score of 3-8. Originally, the definition used in the international studies coordinated from Glasgow,^{22 23} was that the patient was in a coma for six hours, coma being defined as no eye opening, no comprehensible verbal response, and not obeying commands.²⁴ In some 80% of cases the notation for coma translates into a coma score of 8 or less, hence the adoption of the score. The six hour

duration has become difficult to apply as a result of severe head injuries now almost uniformly being sedated, intubated, and ventilated and are hence unassessable for many hours, and initial severity is usually assessed by the findings on admission.

Moderate head injury was defined by Rimmel *et al* as a patient with a coma score of 9-12.²⁵ This group until recently did not receive as much attention as either the severe or lesser injuries. The group may be difficult to identify consistently and the definition needs scrutiny before much further work is carried out.²⁶

The most unsatisfactory definition is of a *mild or even minor* head injury as a patient with a Glasgow coma score of 13-15.²⁷ The problem is that patients with a coma score of 15 make up by far the overwhelming number of patients classified in this group.²⁸ In practice, a patient with a coma score of 15, compared with those with scores of 13 or 14, has a much lower risk of complications at the acute stage^{29 30} and fewer and less persistent subsequent sequelae. The inclusion within the same category of all patients with a coma score of 13-15 underestimates the true severity of the injury in patients with scores of 13 or 14. It also gives an impression of undue seriousness to those with a coma score of 15. It is more appropriate to separate out patients with a coma score of 15 and refer to these as having had a minor injury.

Description of severity in later stages is based on the duration of alteration in consciousness—either of observed coma or of amnesia.³¹ The duration of amnesia after the injury—post-traumatic amnesia—is a widely accepted index. It may be difficult to estimate precisely and is best regarded as a logarithmic scale: very mild, less than five minutes; mild, five to 60 minutes; moderate, one to 24 hours; severe, one to seven days; very severe, one to four weeks; extremely severe, more than four weeks.^{16 32}

The classification of severity based solely on changes of consciousness may sometimes overlook the importance of focal injury. Computed tomography and MRI show that cortical contusions can occur in the absence of prolonged unconsciousness but lead to prolonged confusion and sequelae such as memory impairment and epilepsy.³³

Prevention

Prevention is possible at three stages: forestalling the accident; minimising the degree of

Table 4 Classification of head injuries by the Glasgow coma score into severe, moderate, mild, and minor

	GCS on Arrival	Cases (%) Attenders	Admissions	Multiple Injury (%)	Risk of ICH No fracture	Fracture	Dead (%)
Minor	15	95	42	32	1:10 000	1:100	<1
Mild	13/14	4	38	37	1:380	1:15	3-5
Moderate	9-12	1	13	63	1:50	1:8	9
Severe	3-8		7				35-40

ICH = Intracranial haematoma; GCS = Glasgow coma score.

injury occurring on impact; and reducing the risk of secondary complications—the focus of medical management in the acute stage. Accident prevention requires modification of behaviour by the public and is effective usually only when enforced by legislation. The introduction of speed limits, the use of safety belts by vehicle occupants, and the wearing of helmets by motor cyclists have all proved effective. More stringent limits on the alcohol level allowed in drivers, and the universal use of air bags, with rigorous enforcement could further contribute to a reduction in injuries due to road accidents. This would leave alcohol still a major contributor to injuries from assaults and falls and in pedestrian victims of road accidents. There is increasing evidence that the wearing of helmets by cyclists prevents injuries, but this remains to be backed up by legislation. The dangers of brain damage from boxing are well recognised.³⁴ What doctors should do is to emphasise the inadequacy of current preflight medical examinations in minimising the risk and to point to the long term dangers, highlighted by the increasing evidence of a biological connection between head injury and dementia.³⁵

Diagnosis

Two questions need to be answered in every suspected head injury: is it a head injury, and is it only a head injury? There is little doubt about the occurrence of a head injury when a clear history is available from either the victim or an onlooker. Difficulties arise in the person presenting with impaired consciousness of unknown onset and duration, especially when there is evidence of alcohol intake. There is compelling evidence that when in doubt it is safer to regard the victim as having a head injury than to attribute impaired consciousness to alcohol ingestion or, in the old person with focal signs, to the effects of a stroke.³⁶ Confirmation of an injury to the head may come from careful examination clinically or from the result of a skull radiograph. Conversely, when a head injured patient has impaired consciousness, there is a temptation to focus too much attention to the head and to overlook important injuries elsewhere.³⁷ The initial clinical examination should note carefully any abnormal neurological symptoms or signs as a reference point for comparison with subsequent examinations and interviews. The niceties of the comprehensive neurological examination are, however, of considerably less relevance than regular reliable assessments of consciousness.

Management

The essence of management of head injury is the provision of optimum circumstances for recovery from damage already sustained—principally primary damage—and the avoidance of the development or exacerbation of damage due to complications—principally secondary damage. In the acute stage survival and natural recovery can be expected in most

patients with minor, mild, or moderate injury and hence the focus in these is on the identification of patients at risk of secondary complications—principally a traumatic haematoma. The patient with a severe head injury who is in a coma has both evidence of already having sustained a substantial amount of brain damage and also a much greater risk of both intracranial and extracranial complications.

Assessment, diagnosis, investigation, observation, monitoring, treatment, and rehabilitation each have a crucial part in the management of head injury. The diversity of injuries and variations in resources available mean that there is not a single approach that is optimum for all victims. On the other hand, attempts to tailor management to each individual patient, based on a process of deduction and deliberation, does not provide effective care for head injuries. Instead, as with all trauma, an approach based on a series of recommendations, criteria, or guidelines, is both more efficient and effective. These enable an approach that is consistent between cases and between centres; they reduce confusion and enhance communication and improve outcome.^{38,39} Widely accepted approaches to head injury management have been recently reviewed.⁴⁰⁻⁴³

ASSESSMENT

The approach to assessment varies with the perceived severity of injury. When the patient has impaired consciousness, assessment and resuscitation must follow the principles of life support, as it is taught in the Advanced Trauma Life Support (ATLS) system.⁴⁴ The identification and correction of an obstructed airway, of inadequate ventilation, or shock must take priority over the detailed assessment of the patient's neurological state.⁴³

Assessment can begin at the roadside and ambulance staff can now score patients on the Glasgow coma scale and report the level of blood pressure and heart rate. Unfortunately, many patients still arrive at specialised units either from the scene of an accident or from another hospital with hypoxia, shock, or other factors worsening prognosis.⁴⁵ On arrival at hospital, assessment and resuscitation must be completed before the patient is moved for further investigation or treatment. The temptation to focus on the head and carry out premature CT or other investigations must be resisted in favour of a proper, thorough general survey and management.⁴⁶

Assessment of the patient's neurological state is quickly and effectively carried out with the Glasgow coma scale for overall consciousness, noting any side to side differences in limb movement to detect hemiparesis or other focal neurological deficit and examining the pupil size and response to light.¹⁸ The eye opening, verbal, and motor responses of the Glasgow coma scale are well known and can be modified for application to children under five years old (table 3).⁴⁷ Neurological assessment should be repeated and documented often—for example, at least every 10 minutes

Table 5 Indications for CT and referral of patients with recent head injury (from Teasdale, et al³⁰)

Indications for referral to neurosurgical unit	
Without preliminary computed tomography:	
Coma persisting after resuscitation	
Deteriorating consciousness or progressive focal neurological deficits	
Open injury: depressed fracture of vault or basal skull fracture	
Patients fulfil criteria for CT in a general hospital when this cannot be performed within a reasonable time—for example, three to four hours	
After computed tomography in general hospital:	
Abnormal tomogram (after neurosurgical opinion on images transferred electronically)	
Tomogram considered to be normal but patient's progress is unsatisfactory	
Indications for computed tomography in general hospitals	
Full consciousness but with a skull fracture	
Confusion persisting after initial assessment and resuscitation	
Unstable systemic state precluding transfer to neurosurgery	
Diagnosis uncertain	

during the first hour and then afterwards according to progress. The findings are a valid guide to the extent of brain damage only when the patient is adequately oxygenated and has a normal blood pressure. Any deterioration is a signal to seek complications such as hypoxia, hypotension, or intracranial haematoma.

INVESTIGATION: RADIOLOGY

Computed tomography proved its clinical value rapidly in the diagnosis of intracranial complications after head injury.⁴⁸ Despite its advantages in diagnosis, however, improvement in the outcome of head injury occurred only when the availability of CT was allied to policies aimed at ensuring investigation at an earlier stage, preferably before the occurrence of neurological deterioration.³⁸ Magnetic resonance imaging is more sensitive to parenchymal abnormalities,^{7,49} but the greater availability and practicability of CT make it still the mainstay of acute investigation of head injury, where its value in improving outcome is most clear.

The issue that CT brought into clear focus, and that continues to be controversial, is the triage of patients; what is the optimum match

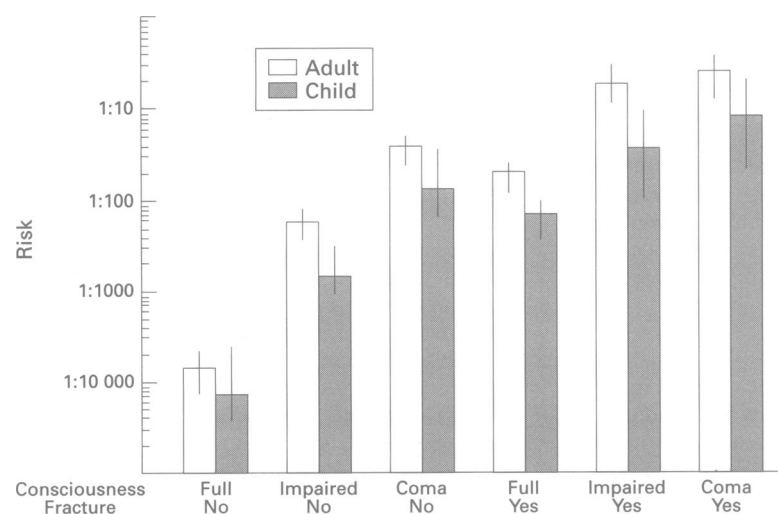


Figure 1 Effect of age, skull fracture, and impaired consciousness and coma on increasing the risk of a traumatic intracranial haematoma (data from Teasdale et al³⁰).

between the number of CT scans that it is feasible to carry out and the likelihood that the investigation will contribute to management?

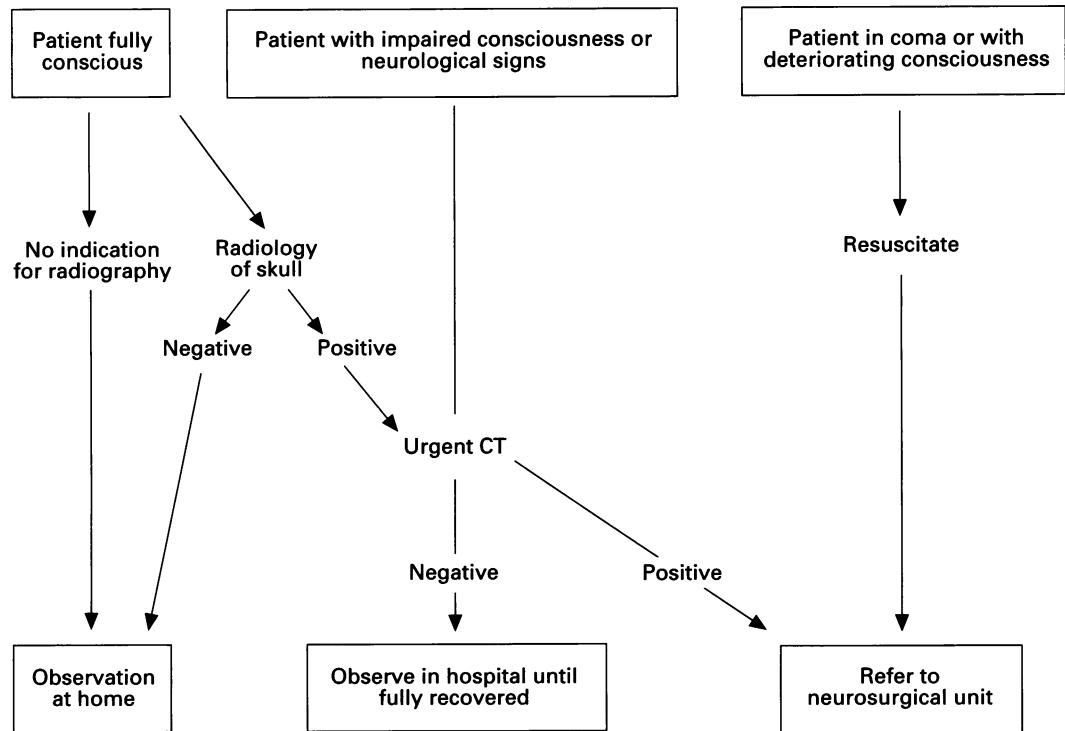
Guidelines for selection of patients for CT were first promulgated a decade ago, when scanners were largely restricted to neurosurgical units.^{50,51} More recently the increasing availability of CT scanners in general hospitals has led to a reappraisal and widening of the criteria for scanning (table 5).³⁰ Unfortunately, the opportunity provided by the availability of CT⁵² in many hospitals is often not turned to the advantage of patients with head injury because access to the scanner is limited to the normal working day, whereas most injuries occur at nights and at weekends. When this is the case, neurologists and neurosurgeons should press for the establishment of an "out of hours service" with, if necessary, image transfer for consultation with the neurosurgical unit. Without an emergency service, the restricted availability of the CT scanner in a general hospital can lead to inappropriate delay before the patient is investigated and a delay in the diagnosis of remediable intracranial complications.⁵³

It is neither feasible nor desirable that all head injuries should undergo CT. Instead, there is now evidence from several studies that the factors that identify the likelihood of a patient having either abnormal CT or a remediable intracranial lesion can be deduced from clinical features.^{30,31,54} The key factors are the depth and duration of alteration of consciousness, the result of a skull radiograph (fig 1) and, in a few cases, the presence of focal neurological signs. Whereas in the past, when scanning required neurosurgical transfer, this could be advocated only in patients with both impaired consciousness and the skull fracture—in whom the risk of haematoma was as high as one in four,⁵¹ it is now more reasonable that all patients with persisting impairment of consciousness after arrival at hospital are considered for CT (fig 2).³⁰ In the patient in a coma, this should follow transfer to the regional neurosurgical unit; in the patient with a coma score between 9 and 14 whose condition does not return to normal within one to two hours of injury, scanning should be carried out locally.

Skull radiographs can be omitted from initial assessment if CT is to be carried out. A skull radiograph, however, retains an important place in the investigation of patients who are fully conscious, in whom the finding of a skull fracture raises the risk of intracranial complications by more than 200-fold. Computed tomography should be performed if a skull fracture is present. The use of CT in all cases is unjustified, because of the greater radiation exposure (some twofold) and the greater cost (twofold to fourfold) compared with a skull radiograph.

Skull radiographs still have value in the detection of fluid levels in the sphenoid sinus, intracranial air, or depressed skull fracture, each of which signals an open injury and the risk of intracranial infection. Indications for

Figure 2 Flow chart for management of patients with head injury according to level of consciousness, skull radiograph, and CT in district general hospitals and regional neurosurgical units (from Teasdale et al⁶⁰).



skull radiographs include high or medium velocity impact with a broad hard surface⁵⁵ and association with other features such as post-traumatic amnesia, leakage of CSF, or bleeding from nose or ears, a large scalp haematoma, or laceration. In the unconscious patient, radiographs should also include films of the cervical spine, chest, and of any areas suspected of associated fractures.

CLINICAL OBSERVATION

The twin purposes of observation and monitoring are the determination of the pattern of evolution of the patient's neurological state and the detection of complications. The intensity of observation and monitoring is determined by the extent of any existing brain damage and the perceived risk of deterioration.

For the patient who is conscious and who does not have a skull fracture, the decision is whether or not to admit to hospital for observation. At least four out of five patients are discharged for observation at home and the proportion of patients admitted can be reduced further without adverse effects.^{56 57} Every accident and emergency department

dealing with head injuries should have an established policy, clearly displayed and widely known. Table 6 shows the accepted indications for admission. Patients who are conscious without any of these features can be discharged for observation under the care of a relative or responsible adult who should be given a list of instructions in the form of a "warning card" about what to observe and what to do. In such low risk cases, admission to hospital confers no advantage when a haematoma does develop.⁵⁸

In the patient who has impaired consciousness but is still talking, assessments of consciousness should be repeated every one to two hours. Cardiovascular respiratory and other "vital functions" can be assessed by customary clinical methods with recordings made intermittently. The more severe the impairment of consciousness, however, the more likely it is that these traditional methods will fail to disclose important deviations from values that ensure satisfactory cerebral perfusion and oxygenation and the greater the indication for continuous and invasive methods.

Table 6 Indications for admission for observation of head injuries

The following list of indications for admission of patients with head injuries should be displayed in accident and emergency departments

- Confusion or any other depression of consciousness at the time of the examination
- Skull fracture
- Neurological symptoms, or signs, or both
- Difficulty in assessing the patient—for example, because of ingestion of alcohol, epilepsy, or other medical conditions that cloud consciousness. Children are also difficult to assess
- Lack of a responsible adult to supervise the patient and other social problems
- Brief amnesia after trauma with full recovery is not necessarily an indication for admission
- If the patient is to be observed outside hospital he or she should be discharged with a head injury "warning card" into the care of a responsible person

Table 7 Monitoring techniques and investigations used in patients with severe head injury (from Della Carte⁵⁹)

Routine	Selective
Glasgow coma score	Intracranial pressure
Pupils	Cerebral perfusion pressure
Temperature	Central venous/pulmonary artery pressure
Arterial O ₂ saturation	Electroencephalogram
End tidal CO ₂	Jugular bulb O ₂ saturation
Arterial blood pressure	Transcranial Doppler
Electrolytes/haematology	CT: on admission; postoperative (24h-72h); if intracranial pressure is raised; if clinical deterioration occurs

MONITORING

Detailed continuous monitoring is needed in all patients who are not obeying commands or who have a head injury and other serious injuries (table 7). Arterial pressure should be monitored with indwelling arterial cannula to provide a continuous record. This will provide access for intermittent measurements of blood gases as indicated by the results of continuous monitoring of arterial oxygen saturation using pulse oximetry. An ECG should be monitored continuously and monitoring of central venous pressure or pulmonary artery pressure may be indicated when shock has occurred or is suspected. In a ventilated patient, the measurement of end tidal CO₂ with a capnograph is a useful check to the adequacy of ventilation, supplemented by the controls inbuilt into modern ventilator systems.

The role of monitoring intracranial pressure in head injuries is still controversial. Although it is not employed in all units dealing with severe head injuries, it has at least two clear benefits.⁴² The first is in providing an indication of severity of space occupying effects from a focal intracranial lesion. The second, when coupled with arterial pressure measurements, is in calculating cerebral perfusion pressure, the critical determinant of overall cerebral blood flow. All techniques are to a degree invasive, however, and have a risk of intracranial infection of 2%-8% and of causing intracranial haemorrhage (< 1%) and epilepsy (1%).

The value of monitoring intracranial pressure in the management of a patient with an intracranial clot became established when it became apparent that CT was showing many more focal lesions than could be expected to require evacuation.⁶⁰ Deciding as soon as possible whether to evacuate a clot in a stable patient minimises the risk of neurological deterioration and improves outcome. Certain CT features show strong correlation with a rise in intracranial pressure and by themselves are indications for evacuation.⁴⁰⁻⁴¹ Such features are pronounced midline shift (1 cm), loss of visualisation of the third ventricle and perimesencephalic cisterns, and dilatation of the ventricle contralateral to the lesion, particularly the temporal horn. When CT features leave doubt about the need for operation, continuous monitoring of intracranial pressure should be instituted and the lesion evacuated if pressure is sustained above 20-25 mm Hg. If the pressure remains below this level for 24 hours, then the likelihood of deterioration is very small. Intracranial pressure should be monitored after evacuation of an intracranial clot to provide an early warning of the development of a recurrent or new haematoma and because after evacuation of a subdural or intracerebral clot brain swelling and raised pressure are frequent.

Intracranial pressure can be monitored by insertion of a fluid filled catheter into the ventricle or, increasingly, by insertion of a solid state fibre optic system into the CSF pathways or direct into brain parenchyma. The first usually requires a burr hole performed in

the operating theatre, whereas the second can be carried out with a twist drill in the intensive care unit. Although the techniques for monitoring intracranial pressure are not necessarily restricted to neurosurgical intensive care, just as an overconcern about the head injury in a comatose patient with multiple injuries can be dangerous, so too can be an overnarrow focus on observing and treating intracranial pressure. Unless monitoring is accompanied by the knowledge and experience necessary to appreciate the importance of first considering the cause of raised pressure before any treatment, and of the need for easy access to and use of repeat CT and other investigations needed to interpret intracranial pressure findings, benefits from monitoring it may be outweighed by adverse effects. Thus it is inappropriate and harmful to attempt to lower intracranial pressure by medical measures when its primary cause is an expanding intracranial lesion requiring evacuation. It is also crucial to be aware that an apparently satisfactory reduction of intracranial pressure—for instance, by hyperventilation or barbiturate treatment - may be at the price of actually inducing cerebral ischaemia as a result of vasoconstriction,¹³⁻⁶¹ or net lowering of cerebral perfusion pressure by concomitant hypotension⁶² and result in a worse outcome.⁶³

Continuous monitoring of jugular venous oxygen saturation can provide valuable information when treating raised intracranial pressure.⁶⁴ A decrease in venous blood oxygenation indicates increased extraction either due to reduction in blood flow or due to an increase in metabolism. Conversely, very high levels of venous oxygenation indicate cerebral hyperaemia. Jugular oxygen saturation can be measured continuously with indwelling fibre optic catheters but, at the present stage of development, readings have to be interpreted with considerable caution because abnormal values can result from technical factors. The catheter should be recalibrated at least every 12 hours against the findings of a co-oximeter on withdrawn blood samples and these should be repeated to check any apparently abnormal values. In the presence of arterial hypoxaemia and anaemia, it is probably preferable to determine the absolute content of blood and hence the cerebral oxygen extraction rather than rely on saturation values. The precise values of venous saturation that are optimum are still being debated; values below 50%-60% indicate excessive extraction and potential for ischaemia, at least regional, and values of 85% indicate hyperaemia.

Cerebral blood flow can be determined intermittently from a variety of techniques, but none of these has as yet found a place in routine management. An index of cerebral blood flow is provided by the velocity of blood flow in the intracranial arteries and this can be measured intermittently or continuously, typically in the middle cerebral artery, using transcranial Doppler sonography.⁶⁵ This non-invasive technique also finds

application in the care of patients with subarachnoid haemorrhage and is becoming increasingly available in neurosurgical units. Changes in mean velocity or in indices of pulsatility—the difference between systolic and diastolic flow velocities—aid the interpretation of information from intracranial pressure measurements and cerebral oxygen extraction values. Velocity falls and pulsatility increases with reducing cerebral perfusion pressure and blood flow. A high velocity can be due to hyperaemia or narrowing of the vessels due to traumatic cerebral vasospasm.

Studies of cerebral electrical activity can provide information about brain function in patients who are unconscious either due to the head injury or because of pharmacological treatment. The potentials evoked by somatosensory stimulation provide a useful index of integrity and are prognostically useful but have not established a value in practical care. When neuromuscular paralysis is employed to permit ventilatory treatment, however, there are advantages in continuous monitoring of cerebral activity using a simplified device such as a cerebral function monitor.

Monitoring with which staff are not familiar or which produces technically capricious results is useless and even dangerous. The increasing complexity of monitoring used in the management of patients with serious head injury is a strong argument for concentrating such cases, and hence experience, in regional neurosurgical centres, where the expertise to carry out the measurements and interpret and act on their findings can be developed and sustained.

Management of traumatic brain damage

The early scepticism, if not pessimism, about the prospects for recovery of a patient who remained in a coma, despite effective early resuscitation, has been dispelled by the evidence from many sources that half or more such victims can recover and make an independent recovery. The prospects for improving the outcome of such injuries have been considerably heightened by evidence from modern methods of monitoring of the occurrence of secondary insults, likely to exacerbate brain damage, that were not detected by methods available a decade or more ago.¹² Such insults worsen outcome¹³ opening the

way to improving an outcome by prevention of secondary insults or minimisation of their consequences. Also, the greater understanding of the pathophysiology of injury that has come from animal experiments and clinical observation in the past decade has enabled the development of more rational policies for management and more appropriate targeted treatment in individual cases.⁶⁶ This is encompassed within the concept of neuro-intensive care, distinguished in its concepts and techniques from general intensive care. No longer is it satisfactory for patients with head injury to be sedated, paralysed, and ventilated in the absence of appropriate neuro-monitoring and investigation facilities.

NON-OPERATIVE MANAGEMENT OF SEVERE HEAD INJURY

This covers a range of techniques employed to prevent and treat complications considered to be liable to produce secondary damage. Many of these complications are systemic—for example, hypotension, hypoxia, hypercapnia, hypothermia, electrolyte imbalance—rather than intracranial. The need for meticulous standards of management of severely injured or ill patients, and the methods involved apply just as much to a serious head injury. As a general principle, such systemic disturbances are both more common and more serious in their effects than intracranial disturbances,⁶⁷ even after the initial resuscitation and emergency measures have been carried out.¹⁴ By contrast with the unanimity about the importance of these factors, there is still considerable variation of opinion about the employment of methods primarily aimed at treating raised intracranial pressure and brain swelling after head injury. This is partly because such methods have not been shown by a randomised control trial to substantially improve outcome, and it is difficult to conceive of the feasibility of carrying out such a trial. Also, it reflects the fact that brain swelling and raised intracranial pressure may be a consequence of brain damage, rather than a primary factor in producing damage. There is, nevertheless, an acceptance that the supervision of raised intracranial pressure, reduction in cerebral perfusion pressure, and ischaemia on an already damaged brain, with heightened vulnerability as a result of injury⁶⁸ cannot be other than undesirable.⁶⁹

Ventilation of unconscious patients is widely used (table 8). The aim should be to keep arterial oxygen saturation as close as possible to 100%, using increases in inspired oxygen and positive end expired pressure when necessary. Ventilation should be adjusted to maintain arterial CO₂ tension normal or slightly subnormal. The practice of equating ventilation of head injury with hyperventilation must be abandoned in view of the evidence of the resulting cerebral hypoxia and impaired outcome that result.^{13 63} Hyperventilation should be employed only briefly, not least because its effects are only temporary. Hypotension, whether as a consequence of hypovolaemia due to inadequate

Table 8 Indications for intubation and ventilation of patients with recent head injury (from Gentleman *et al*⁶³)

Immediately:
Coma (not obeying, not speaking, not eye opening)—that is, Glasgow coma score \leq 8
Loss of protective laryngeal reflexes
Ventilatory insufficiency (as judged by blood gases):
Hypoxaemia (PaO ₂ < 9 kPa on air or < 13 kPa on oxygen)
Hypercarbia (PaCO ₂ > 6 kPa)
Spontaneous hyperventilation causing PaCO ₂ < 3.5 kPa
Respiratory arrhythmia
Before transport within or between hospitals:
Significantly deteriorating conscious level, even if not in a coma
Bilaterally fractured mandible
Copious bleeding into mouth (for example, from skull base fracture)
Seizures
An intubated patient must also be ventilated; aim for PaO ₂ > 15 kPa; PaCO ₂ 4.0–4.5 kPa
PaO ₂ = arterial oxygen tension; PaCO ₂ = arterial CO ₂ tension.

fluid replacement, or the use of sedative depressant drugs must be avoided.

When raised intracranial pressure occurs and simple causes such as neck position, airway obstruction, abnormal breathing patterns, fever, and seizures, have been excluded and a surgically remediable intracranial lesion occupying space has been ruled out, two principal approaches to treatment are employed. The first is the use of osmotic diuretics such as mannitol with a view to withdrawing fluid from either the normal brain or areas of brain oedema. The usual starting dose is 0.5 g/kg body weight with adjustment as determined by the effects on intracranial pressure and cerebral perfusion pressure. Additional measures include frusemide to sustain the osmotic gradient, infusion of colloid to maintain circulating volume, and the avoidance of hyperosmolarity (serum osmolarity more than 320 mmol/l). The alternative is to use sedative or hypnotic drugs such as propofol or thiopentone to reduce cerebral metabolism and hence induce a fall in blood flow and blood volume.

Mannitol is considered to be most effective in raised pressure due to focal space occupying lesions whereas sedatives are more appropriate in patients with raised intracranial pressure due to vascular dilatation—typically children with preserved cerebrovascular CO₂ activity and cerebral electrical activity.⁶⁵ In all circumstances, care must be taken to avoid hypotension and it is sometimes more appropriate to maintain cerebral perfusion pressure by raising blood pressure pharmacologically than to strive to reduce intracranial pressure.

DRUG TREATMENT OF HEAD INJURY:

NEUROPROTECTION

Various agents have been used or are being considered that aim to interfere with the molecular, biochemical, cellular, and microvascular processes involved in traumatic brain injury.⁷⁰ None has yet been shown clearly to be of benefit. This is particularly true of steroids. After many years of debate, several trials at various doses have failed to show beneficial effects and even adverse consequences have been noted.⁷¹ This contrasts with the benefit of steroids in brain swelling due to tumour and highlights the mechanistic differences in the processes.

The increased understanding of traumatic and ischaemic brain damage that has come from intense research in recent years has pointed to the importance of mechanisms such as increased intracellular calcium, excitotoxicity from excessive glutamate and other excitatory amino acids, and lipid peroxidation.⁷² There are promising indications from experimental studies of benefit from a range of neuroprotective drugs—calcium ion channel antagonists, glutamate receptor blocking agents and antioxidants—and also hypothermia. Clinical studies are underway or planned.

Most neuroprotective agents have side effects on cardiovascular and CNS function and the achievement of an acceptable efficacy

and safety margin is likely to depend on the patient receiving effective neurocritical care. Certainly, this will be necessary in the trials needed to determine efficacy and the concentration of severely injured patients in appropriate facilities should be encouraged.

ANTICONVULSANTS

The frequency of seizures (5%), both in the acute and late phase after head injury⁷³ has prompted the use of anticonvulsant drugs as a prophylactic measure rather than as a response to a declared epileptic event. It was hoped that prophylactic treatment and the suppression of seizure events would lead to a reduced occurrence of late continuing seizures. Trials have shown that this is not the case for such late epilepsy.^{74 75} One study, however, has shown a clear reduction in seizures but only in the first week after injury.⁷⁶ The precise level of risk of seizures that merits treatment remains debated; like most British neurosurgeons, I prefer to withhold treatment until such time that a seizure occurs.

ANTIBIOTICS

There is controversy also about the use of antibiotics in the prophylaxis of infection in patients with an open injury, particularly due to a fracture at the base of the skull resulting in CSF rhinorrhea, or otorrhea, or intracranial air. One school of thought argues that the use of broad spectrum antibiotics does not reduce infection and simply promotes the occurrence of antibiotic resistant bacteria. On the other hand, I believe that there is reasonable recent evidence⁷⁷ to support the long suspected value of prophylaxis with penicillin or allied agents, against pneumococcus, which is the most common organism and which can cause explosive and irreversible deterioration.

OPERATIONS IN HEAD INJURY

Most intracranial haematomas after a head injury are intradural—subdural, intracerebral, or both. Effective operative management of these lesions demands more access than can be achieved by a burr hole and requires neurosurgical and neuroanaesthetic expertise and facilities. With early referral for CT, there now should be very few, if any, occasions that a non-neurosurgeon needs to contemplate intracranial surgery—even for the simpler but much more rare solitary extradural haematoma. When a haematoma is detected or strongly suspected, a large bolus of mannitol—for example, 1 g/kg—can “buy time” for transfer to the neurosurgical operating theatre.

Intracerebral contusions and smaller haematomas can pose difficult decisions. Some surgeons favour a conservative approach: intracranial pressure is monitored and if raised, especially if cerebral perfusion pressure is reduced, medical methods are used and operation performed only if these fail. Although a conservative approach may be reasonable initially, if intracranial pressure is raised and the CT shows a focal space

occupying, mass effect, operation should be preferred. Evacuation does not risk injury to surrounding recoverable brain tissue—areas of low CT density adjacent to a contusion identify cytotoxic oedema in irreversibly damaged brain; evacuation of a mass lesion will always be a more secure method of improving intracranial pressure-volume relations, and fatal herniation can occur from local shift while intracranial pressure is being “controlled” medically.

Open injuries are less urgent indications for operation. Debridement and repair of a compound depressed skull fracture within 12–24 hours of injury avoids or minimises infection. Repair of a basal skull fracture is usually postponed until any associated leakage of CSF has persisted for several days, at which time the frontal lobe swelling, due to the contusions customary in such cases, has subsided. There is a trend for early (< 12 hours) operation in craniofacial injury, the optimum time for correcting deformity, but this should be avoided if an associated head injury is any more than minor or mild severity.

Where should head injuries be treated?

Provision of care for head injuries needs to incorporate the assessment and arrangement for home observation of the minor injuries that make up 80% of hospital attenders; arrangements for admission and observation of mild and moderate injuries; CT, either before or after neurosurgical referral and transfer; and for the resuscitation, continuing care and definitive management of patients with a severe head injury or a head injury combined with serious injuries elsewhere.⁷⁸

Facilities needed for initial assessment include staff trained and able to assess consciousness, to apply guidelines for skull radiography, to interpret its findings, and to apply guidelines for discharge or hospital admission. These must be available at all times within a district general hospital that deals with trauma cases. The arrangements for cases needing admission to hospital will depend on whether the hospital also contains a neurosurgical unit. If this is not so, it is preferable for head injuries admitted for observation to be grouped together in a specific short stay or observation unit where expertise and experience can be maintained in assessment and, where necessary, referral onwards; it is less satisfactory for patients to be admitted for observation on acute surgical wards, whether general surgical or orthopaedic.

Transfer of a patient both within a hospital and from a district hospital to a neurosurgical unit is fraught with hazard.^{12 79} The distance travelled is less important than the risk of changes in homeostasis developing insidiously, unnoticed and untreated, because of inadequate monitoring, equipment, or inexperienced escort.^{45 80–82} Dedicated transfer teams, travelling from major centres to collect severely ill patients have been shown to be of value⁸³ but most often the responsibility will

lie with the staff of the referring hospital. Before transfer, the patient must be rendered stable; life threatening extracranial injuries demand priority.⁸⁴ If there is any concern about airway or oxygenation, intubation and ventilation should be established. The staff accompanying the patient should be experienced in the care of the unconscious injured patient. The minimum is a doctor, preferably an anaesthetist or a doctor with anaesthetic training and experience, and a trained nurse or paramedic. They must be familiar with the patient's condition before the journey, with what can go wrong during transport, and with the procedures and equipment needed. During transport there must be reliable intravenous access, the ECG should be monitored continuously as should the blood pressure and arterial oxygen saturation by pulse oximetry. The monitoring equipment should preferably have the ability to display trends, to store data, and to print hard copy for later analysis. Facilities must be available to reposition or replace an endotracheal tube to continue ventilation if the oxygen supply fails, to continue or replace intravenous treatment, and to deal with cardiac arrest. With an appropriately equipped ambulance and adequately experienced staff, road transport will be appropriate for most transfers, air transfer being needed only for inaccessible locations or for very long distances.⁸⁵

The preferred location for the definitive and continued management of the severely injured patient is the regional neurosurgical centre, and neurosurgical intervention is highly cost effective.⁸⁶ Although district general hospitals can increasingly undertake CT, and provide general intensive care, the temptation to retain severely injured patients in whom CT seems not to show a surgical complication should be resisted. As stressed above, the expertise needed to interpret CT scans, to decide on the need for repeat scanning, to carry out and interpret comprehensive “neuromonitoring”, and to apply its results, requires the build up and continuation of expertise; experience depends on a case load of sufficient numbers that is likely to be found only in a regional centre. Acting against this are the factors, professional prestige and market forces, that lead to pressures not to transfer such patients for neurosurgical care but to manage them in general intensive care units in a general hospital. This limits the employment of comprehensive neurocritical care and also divorces the victim's family from the informed advice, counselling, support, and follow up that should be available in a specialised unit.

The merits of “trauma centres” are currently under debate and investigation. Proponents emphasise the benefits of early multidisciplinary intervention in patients with serious multiple injuries. Others point to the very small proportion of accident victims requiring such intervention and the difficulties in selecting out such patients, in arranging for their transport to a dedicated single centre, and in the centre being adequately

staffed at all times, when appropriate cases may be sporadic and unpredictable. Whatever the cause of multiple injuries, an injury to the head has the greatest influence on outcome.⁸⁷

When a trauma centre exists or is being developed in a hospital in which there is also a neurosurgical unit, neurosurgical advice and intervention should be readily available but should not take priority over the diagnosis and management of serious systemic injuries, hypotension in particular being an adverse factor to the recently injured brain. In practice, injuries requiring the intervention of another surgical specialty occur in only a few patients with head injury, even those with a severe injury. Miller (personal communication) found that of 440 admitted head injuries, only 14 needed an orthopaedic operation, four a maxillofacial operation, and three a general surgical operation but 80 needed a neurosurgical procedure. It is, therefore, more appropriate for a head injury, after initial resuscitation, to be transferred with appropriate safeguards for neurosurgical assessment and management in a fully equipped unit with round the clock neurosurgical cover. The Society of British Neurological Surgeons has strongly recommended in *In Safe Neurosurgery* that trauma centres should be developed only in hospitals with a neurosurgical service. It is doubtful that without this any centre can regard itself as offering comprehensive trauma care.

Outcome, prognosis, and prediction

The outcome that can be expected after a head injury is of much concern to a victim's relatives and carers.⁸⁸ The traditional approach of doctors has been to stress the uncertainty of the situation—borrowing the Hippocratic aphorism “no head injury is too trivial to ignore nor too serious to despair of”—coupled with an emphasis on pessimism (“hanging crepe”) to prepare the relatives for death or disability and to protect staff from criticism when this ensues. Reasonably reliable predictions of expected outcome can, however, be made on the basis of the wealth of data described over the past two decades.^{16 89 90} When considering prognosis, certain safeguards must be applied; an estimate of prognosis made too soon after injury is fallible when the patient's condition is partly a reflection of a high alcohol or low oxygen level, correction of which may lead to rapid recovery, or when delayed complications supervene and lead to subsequent deterioration. A balance needs to be struck between the accuracy of later predictions and their lesser usefulness in practice.

In the individual patient one of the most important prognostic factors is age, outcome worsening progressively with the increasing age. By incorporating the additional information about the severity and type of brain damage gained from clinical observations (consciousness, motor patterns, pupil reactions, eye movements)⁹¹ and investigations such as CT⁹² an increasingly clear and reliable

estimate of the probable outcome can be given for individual patients. Murray *et al*,⁸⁹ used a simple computer program to calculate outcome probabilities for a large series of patients with head injury and studied the effect of providing clinicians with predictions at the time that a patient was under acute management. Although this did not alter management overall, intensive methods were used less among patients with a very poor prognosis and were redirected towards patients with an intermediate, uncertain prognosis, for whom outcome was presumably less predetermined and who had more potential to respond.

Outcome after head injury depends predominantly on the degree of mental sequelae, in particular changes in personality and information processing and, in only a few patients, on the degree of any persisting physical limitations.⁹³ For this reason, scales developed for patients with stroke or other types of neurological damage are inappropriate in the head injury population. The Glasgow outcome scale described by Jennett and Bond⁹⁴ distinguished three classes of conscious survival, in terms of consequent handicap: the severely disabled patient, who is unable to live independently and unable to shop or travel on public transport; the moderately disabled patient, who is independent but does not resume previous employment or social lifestyle; and the patient who makes a good recovery, but who is not necessarily free from neurological and neuropsychological limitations.

After severe head injury, 10%–20% of patients remain severely disabled for six months or longer. At this stage only 1%–3% are categorised as being vegetative; hardly any of these subsequently improve to be even severely disabled and none make an independent recovery. On either side of these outcomes, the distributions of deaths and independent recovery have an inverse relation, depending on the population considered. For severe injuries, defined as not obeying commands, the proportion of deaths is 30%,⁹⁵ when in addition the patient is in a coma, with no eye opening and no comprehensible verbal response, mortality is 35%–40%⁹⁶ and when this state has been present for six hours or more, mortality approaches 50%.¹

After moderate, and in particular, mild head injury, most patients are at worst only moderately disabled and the original Glasgow coma scale⁹⁴ has been criticised as too crude for such populations.⁹⁷ The device of defining upper and lower levels in each category of conscious survival only partially removes this difficulty.⁹³ A wide range of neuropsychological tests⁹⁸ and inventories of emotional, behavioural, and social status have been described but no single one has yet been widely adopted. In assessing outcome, it is crucial that information is not obtained only from the patient or even from the family practitioner.⁹⁹ A true picture of the patient's state, and in particular of its impact upon the family as a whole can be obtained only when

psychologists are involved in the assessment and where the family and carers are interviewed. This is particularly important if a patient is being assessed for the purposes of a claim for damages, when an underestimate of the consequences of injury may have adverse effects upon the settlement for the patient and perhaps expose the assessor to subsequent criticism.

Postacute care

After discharge from acute care, a range of problems arise. On the one hand, there is the need, in those with persisting limitations, for effective rehabilitation, support, and reintegration to minimise handicap. On the other, there is the problem of the management of patients without obvious physical or mental sequelae but with persisting symptoms and restrictions in activity.

Although there has been considerable controversy over the efficacy of rehabilitation for head injury, there is evidence that it is beneficial particularly when begun soon after injury and provided intensively by specialists in neurological problems.^{100 101} Unfortunately, many patients fail to receive the "seamless" continuity of management that is optimum.¹⁰² This deficiency reflects both the shortage in the United Kingdom of appropriately trained and experienced specialist services and the chasm that often lies between acute medical services and community services. Moreover, most rehabilitation services and therapists are directed towards specific physical limitations and their consequent disability, whereas mental limitations are much more important after head injury in causing disability and handicap and limiting return to previous social and working lifestyles.

Macauley's aphorism "The business of everybody is the business of nobody",¹⁰³ can be applied to head injuries. A wide range of professional disciplines, of support services, and of charitable and voluntary organisations can contribute to the recovery of a head injury victim. They need to be coordinated effectively and specific interventions used appropriately and selectively. Unfortunately, all too often coordination and communication is lacking and, given the range of problems after head injury, it can be tempting to regard the patient as "somebody else's problem". In some parts of Britain no effective organisation exists, in others the organisation is appropriate but facilities needed for benefit are inadequate; in a few centres, comprehensive progressive rehabilitation and community reintegration are available. All concerned should press for the institution in every region of an integrated policy for postacute care of head injury. Someone should be given the responsibility of establishing the service and for arranging for its implementation; in effect this person's job should be to make sure that everyone else does their job!¹⁰⁴

At the time of discharge from hospital the patient and the family should be counselled about the nature of the head injury, its likely

sequelae in the short term, and the likelihood of progressive recovery. Sufficient information should also be conveyed to the general practitioner about the nature and severity of the head injury and the initial approach to subsequent care. In the patient with a minor or mild injury all that may be needed is reassurance, relief of symptoms—for example, headache—and arrangements for review and return to activities after an interval that is determined by the severity of injury and subsequent symptoms. In the uncomplicated mild or minor injury, review by the general practitioner after a week may show a satisfactory progress, enabling return to work. This should be discouraged, however, if symptoms present at discharge—for example headache, dizziness, or mental limitations—persist or become exacerbated. At around a month after injury, patients who continue to have a significant problem should be referred or recalled for assessment and for planning of rehabilitation and reintegration socially, professionally, etc. This service would be facilitated if a regional register of head injuries was established, with close liaison with neurosurgical unit staff. Subsequently, further remedial services may be required for a year or longer, depending on the patient's progress and the findings of subsequent assessments.

Quality of care: audit

Analysis of the management and the outcome from head injuries has already resulted in changes in practice that have been rewarded by better results. In the early 1970s some studies showed that avoidable mortality in patients with head injury occurred often due to delayed recognition of the presence of an intracranial haematoma.^{36 105 106} The recognition that CT could detect haematomas before they caused deterioration and the identification of clinical features correlating with the likelihood of a haematoma, enabled the production of guidelines aimed at early referral to neurosurgery. These were first used informally within the neurosurgical unit in Glasgow⁴⁹ and then published and widely adopted nationally.⁵¹ Continuing audit of outcome has shown that these changes in procedure were accompanied by reductions in mortality in operated cases (table 9).^{49 57 89}

Insults during transfer from district hospital to neurosurgery were identified as another source of brain damage and death and

Table 9 Introduction of guidelines for management of head injuries and associated improvements in outcome of patients with a traumatic intracranial haematoma (INS Glasgow)

	Total (% dead)
1974-7	
Referred to neurosurgery when clinically deteriorating	305 (38)
1978-84	
Local criteria for earlier acceptance	659 (30)
1985-8	
Published national guidelines for earlier referral	222 (23)

disability that might be avoided by a better standard of care during transfer.⁴⁵ Dissemination of this knowledge led, over a period of 11 years, to a rise from 11% to 82% in the use of endotracheal intubation and ventilation in transfer. This was associated with a fall in hypoxaemia on arrival from 22% to 8% and a reduction in the number of unidentified or undertreated major extracranial injuries from 31% to 11% and in hypotension from 11% to 6%. Mortality fell from 45% to 32% and independent recovery rose from 40% to 58%.⁷⁹

It will be important in the future to ensure that the gains resulting from the foregoing neurosurgically and neuroanaesthetically led improvements in practice are maintained against the background of alterations in the organisation of medical care (for example, trust hospitals, internal markets) and the dissemination of previously centralised facilities (for example, CT). Each health purchasing authority should identify standards of practice, based on the guidelines for the process of care. Contracts with providers should contain these specific recommendations and should require that audit is carried out to ensure that they are being used properly.

Questions to be asked include what proportion of head injury attenders undergo skull radiography, hospital admission, and neurosurgical transfer and with what outcome? Samples should be surveyed in detail to discover if practice in regard to individual patients conforms with the agreed standards. The quality of interpretation of investigations should be checked. Where skull radiographs are interpreted by accident and emergency staff, all radiographs should be reviewed by a senior radiologist. Likewise, CT performed outside the neurosurgical department should be reviewed, either at the time through image transfer and consultation with an experienced clinician in the neurosurgical centre, or as a matter of routine periodic quality assessment.

Every death of a patient who arrives at hospital with a head injury, or at the very least all cases in which the patient was known to have talked after injury, should be subject to detailed review at regional level. Without overview at this level, the dispersal of head injuries to different hospitals and even different departments means that audit at unit level will not be satisfactory.

Improved outcomes for head injuries have been achieved by the standards in management described in this review, that have developed in the past decade. It is essential to safeguard these standards as the foundation for building systems for even better care in future.

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