The Neuropathology of Head Injury

**Acute head injury**

**Epidemiology**

In the United Kingdom more than 150,000 patients are admitted to hospital each year with an acute head injury. Of this group more than 80% are classified as having a mild head injury, as defined by the Glasgow Coma Scale (GCS). Approximately 1–2% of patients admitted to hospital after traumatic brain injury die as a consequence of their injuries with the majority of fatalities being within the severe head injury group.

In the acute phase the neuropathology of blunt force head injury can be divided into two principal categories: 1) focal; and 2) diffuse (see table).

**Haematomas**

Intracranial haemorrhage is the most common cause of clinical deterioration and death in patients who experience a lucid interval after head injury. Haematomas may act as a mass lesion and produce secondary effects. Extradural (EDH), subdural (SDH) and intracerebral (ICH) haematomas can all be associated with traumatic brain injury.

EDH’s are seen in some 10% of severely head injured patients, 80% being associated with skull fractures and the majority involve the middle meningeal artery with fractures of the squamous temporal bone.

SDH’s tend to be more extensive than extradural lesions as blood can spread more freely within the subdural space (Figure 1). The majority are due to disruption of parasagittal bridging veins.

ICH’s may be superficial, usually associated with contusions, or they may be more deeply seated, usually within the basal ganglia. When an intracerebral lesion is in continuity with a subdural haematoma the term “burst lobe” is used.

**Contusions**

These are seen in approximately 90% of fatal cases of traumatic brain injury, although they may be absent in some 6% of fatal cases. They are more commonly seen at the crests of the frontal and temporal gyri than within sulci and occur principally at sites where the brain comes in contact with the uneven bony surfaces of the base of the skull. Contre-coup lesions on the opposite side of the brain to the site of impact are thought to be due to negative pressures built up as the brain moves in relation to the skull at the moment of impact. Patients with contusions may show sudden clinical deterioration, particularly those with extensive bifrontal lesions.

**Diffuse injury**

Three forms of diffuse brain injury are seen as a consequence of trauma; diffuse ischaemic injury, which involves grey matter, diffuse traumatic axonal injury (TAI), which involves white matter, and brain swelling.

While focal infarcts are commonly seen after fatal traumatic head injury (91% in one study), usually as a consequence of raised intracranial pressure (ICP), global cerebral ischaemia is less common. Global cerebral ischaemia may be related to hypotension, e.g. after multiple injuries, or secondary to raised ICP resulting in reduced cerebral blood flow. Ischaemic neurons are widely distributed, initially following a pattern of selective vulnerability.

Diffuse traumatic axonal injury (TAI) describes a diffuse process in which there is disruption to axons in a number of white matter bundles throughout the cerebrum and brainstem (Figure 2). Axons are damaged as a consequence of rotational forces being applied to the brain, and is most frequently seen in high velocity impacts such as road traffic accidents. TAI is not a static process. A small proportion of axons may be damaged at the time of head injury (primary axotomy), but animal experiments suggest this is not the case for most of the damaged axons, which degenerate over a period of time after the head injury (secondary axotomy). The clinical impact of TAI ranges from mild diffuse injury being associated with short spells of unconsciousness and possibly concussion, through to extensive diffuse TAI associated with irreversible coma and death. The structural basis of concussion is poorly defined. However, TAI has been described in mild head injury and axonal damage has been demonstrated in animal models of concussion.

**Brain swelling** can develop either locally, such as in relation to contusions, or can be diffuse involving one or both hemispheres. In diffuse brain swelling ischaemia is the most common underlying pathology, although swelling can be associated with diffuse TAI.

**Long term outcome**

The outcome is modified by the type and severity of injury and may be influenced by the pre-morbid state such as age, nutritional status and pre-existing disease. Among survivors of traumatic brain injury of all grades of head injury, as defined by the Glasgow Coma Scale (GCS), approximately 1–2% of patients admitted to hospital after traumatic brain injury die as a consequence of their injuries, with the majority of fatalities being within the severe head injury group.

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Dr Colin Smith trained in neuropathology in Glasgow and is currently a Senior Lecturer in Pathology in Edinburgh. His main research interests are related to traumatic brain injury, both adult and paediatric. In particular he is involved in studies of mechanisms which may contribute to the ongoing neurodegeneration in survivors of head injury.

Figure 1: Subacute subdural haematoma identified at autopsy. This individual had a blunt force head injury as the result of a fall. The patient survived for two weeks post injury. The lesion extends over the surface of the right cerebral hemisphere and shows some degree of organisation.
chronic disability may have a physical component although it is predominantly the cognitive and behavioural problems which provide the greatest challenge. Outcome may be assessed by the extended Glasgow Outcome Scale (GOS) which defines four outcome states: death/vegetative state, severe disability, moderate disability, and good recovery.

Neuropathological basis of outcome after head injury
In studies of the brains of patients who entered a vegetative state after blunt force head injury, diffuse pathology was common and, in particular, diffuse traumatic axonal injury was seen in more than 60% of the cases. In severe disability there was a relatively equal distribution of focal and diffuse pathology between cases, while in moderate disability focal lesions, particularly evacuated intracranial haematomas, accounted for the bulk of the pathology with diffuse injury being uncommon. Neuronal loss from the dorsomedial thalamic nucleus was seen in all grades of disability while additional damage to the ventral posterior nucleus was also seen in severely disabled and vegetative cases.

Neurodegeneration and Dementia after head injury
Recent studies have indicated that the incidence of moderate and severe disability in young people and adults one year after mild head injury is similar to that seen in survivors of moderate and severe head injury. This raises the possibility of ongoing brain damage in long-term survivors of head injury such that their cognitive function and motor function continues to deteriorate for months and possibly years after the initial injury. The clinical entity of dementia pugilistica is well recognised in the setting of repetitive head injury. Epidemiological evidence looking at an association between a single episode of head injury and subsequent neurodegeneration is conflicting although meta-analysis of both retrospective and prospective studies does suggest an association. Head injury and Alzheimer’s disease (AD) have similarities in relation to protein and cellular responses and in genetic influences, particularly the influence of APOE polymorphisms. Both cytoskeletal pathology and amyloid deposition are key pathological features of AD and have been described in animal models of head injury and studies of both fatal head injury and repetitive head injury in humans. Cholinergic dysfunction has been described in both AD and head injury: damage to key cholinergic pathways (nucleus basalis of Meynart) has been reported at autopsy in head injury and imaging studies of survivors of head injury have demonstrated damage to basal forebrain structures. Chronic neuroinflammation has been postulated as a mediator of neuronal loss in many chronic neurological diseases, including AD, and is a feature of the response to head injury (Figure 3).

References