1. Natural History of Acquired Brain Injury

On behalf of the ERABI Research Group

1.1 Defining Traumatic Brain Injury (TBI)

Q. Describe a classification of injuries suffered during Traumatic Brain Injury.

Answer

Primary (Injuries occurring immediately as a direct result of trauma)

- Injury to scalp
- Fracture of skull
- Surface contusions/lacerations
- Intracranial hematoma
- Diffuse axonal injury
- Diffuse vascular injury
- Injury to cranial nerves and pituitary stalk

Secondary (Injuries at cellular, tissue and systemic levels following a primary traumatic injury)

- Hypoxia-ischemia
- Swelling/edema
- Raised intracranial pressure and associated vascular changes
- Meningitis/abscess (p.28; Gennarelli & Graham 2005).

Q. Describe the two major mechanisms of brain injury after trauma.

Answer

Contact

- Injury to scalp
- Fracture of skull with or without associated extradural hematoma
- Surface contusions and lacerations and associated intracerebral hematomas

Acceleration/Deceleration

- Tearing of bridging veins with the formation of subdural hematoma
- Diffuse axonal injury, tissue tears and associated intracerebral hematomas
- Diffuse vascular injury (p.28; Gennarelli & Graham 2005).

1.2 Diffuse Axonal Injury

Pathophysiology of Diffuse Axonal Injury

Q. Describe diffuse axonal injuries.

Answer

- Diffuse axonal injuries are seen exclusively following a TBI and results from accelerationdeceleration and rotational forces associated with a high-velocity impact (Estes & Urban 2005).
- Physical shearing of axons results in hemorrhage, tissue tears, axonal swelling and the formation of axonal bulbs acutely (Morales 2007). Subacutely clusters of microglia and macrophages are seen, while chronically Wallerian degeneration occurs.
- Diffuse axonal injury can be responsible for the initial loss of consciousness seen in acute TBI.
- Damage is most often seen within midline structures and at interfaces between gray and white matter.

The predominant causes of diffuse axonal injury include:

- 1. High-speed motor vehicle collisions above 15 mph or 24 km/h.
- 2. Shaken baby syndrome.
- 3. High-speed collisions in sports (i.e. football, hockey, soccer, rugby; see Figure 1).

Rotational forces can cause diffuse tearing of neural processes and blood vessels throughout the white matter resulting in diffuse axonal injury. Hemorrhagic changes involving the midline structures are often associated with rotational acceleration and tend to involve the parasagittal white matter, corpus callosum, structures in the walls of the third ventricle and striatum (basal ganglia; Goldberg 2001). Strain tends to be concentrated at the interfaces between gray and white matter, at the midbrain juncture between the brainstem and diencephalon, and at the juncture between the corpus callosum and the cerebral hemispheres (Goldberg 2001).





Figure 1. Diffuse Axonal Injury

Q. Describe the pattern and frequency of diffuse axonal injury in severe TBIs (p.34; Gennarelli & Graham 2005).

Answer

Pattern	Frequency (%)
Dorsolateral sector of upper brainstem	. 95%
Corpus callosum	. 92%
Choroid plexus of third ventricle	. 90%
Parasagittal (gliding) contusion	88%
Hippocampus	. 88%
Periventricular (third ventricle)	. 83%
Intraventricular septum	. 80%
Cingulate gyrus	. 61%
Thalamus	. 56%
Basal ganglia	17%

Clinical Features of Diffuse Axonal Injury

Q. Describe some of the clinical features seen following diffuse axonal injuries.

Answer

- Rostral brain stem involvement results in initial loss of consciousness, poor attention and concentration.
- Corticospinal tract involvement results in hemiparesis.
- Shearing of the grey-white matter junction results in slowed mental processing and fatigue.
- Cerebellar peduncle involvement results in ataxia.
- Brainstem injury involvement results in dysarthria and dysphagia.

Impact of Diffuse Axonal Injury on Recovery and Rehabilitation

Q. How does diffuse axonal injury impact recovery and rehabilitation?

Answer

- Disrupted connections between nerves results in slowed mental processing, fatigue, poor attention and concentration.
- Rehabilitation must be organized in a manner that compensates for these difficulties.
- Physical and cognitive stamina may be reduced and proper pacing will need to be implemented.
- Poor attention combined with memory difficulties and behavioural concerns may require attendant care.

Natural History of Diffuse Axonal Injury

Q. What are the three principal stages of recovery following a diffuse axonal injury?

Answers

- Loss of consciousness
- Post-traumatic confusion and amnesia
- Post-confusional restoration of cognitive function

The amount of time required for a patient to demonstrate signs of recovery is proportional to the initial injury severity. Recovery occurs in three stages: 1) Loss of consciousness; 2) Post-traumatic confusion and amnesia (PTA); 3) Post-confusional restoration of cognitive function. The each phase of recovery is proportionally related to the other phases; generally each phase lasts longer than the previous one. This pattern of recovery can be described using the Rancho Los Amigos Level of Cognitive Functioning Scale (RLA).

Rancho Los Amigos Scale of Cognitive Functioning

Q. Describe the Rancho Los Amigos Level of Cognitive Functioning Scale.

Answer

- It is used to monitor recovery following a brain injury.
- It is not an outcome measure but rather a global index used to describe awareness, environmental interaction and behavioural competence.
- The scale describes eight stages of cognitive functioning that an individual with a brain injury typically experiences (Hagen et al. 1972).

Level	Clinical Presentation	Functional Level
Ι	No Response	Total Assistance
П	Generalized Response	Total Assistance
III	Localized Response	Total Assistance
IV	Confused/Agitated	Maximal Assistance
V	Confused, Inappropriate Non-Agitated	Maximal Assistance
VI	Confused, Appropriate	Moderate Assistance
VII	Automatic, Appropriate	Minimal Assistance for Daily Living Skills
VIII	Purposeful, Appropriate	Stand-By Assistance
IX	Purposeful, Appropriate	Stand-By Assistance on Request
X	Purposeful-Appropriate	Modified Independent

Table 1. Rancho Los Amigos Levels of Cognitive Functioning (Hagen et al. 1972)

Note: Levels IX and X are included in the revised RLA Scale (Hagen 1997).

Q. Describe advantages and disadvantages of Rancho Los Amigos Levels of Cognitive Functioning Scale.

Answer

Advantages

- Provides a quick and simple snapshot of the patient's level of recovery (Johnston et al. 1991).
- It has been evaluated and is useful for longitudinal assessments (Hall 1997).
- It can be used/administered free of charge (Hagen et al. 1972).
- Ratings are derived from observation and result in little or no patient burden (Hagen 1982).
- It is useful for making comparisons between patient groups (Hall & Johnston 1994).
- Simplicity and utility have resulted in widespread use (Hall 1997; Hall & Johnston 1994).
- The Levels of Cognitive Functioning Scale is used widely in the United States and provides a quick, global picture of level of recovery.
- Ratings are derived from observation and represent little or no patient burden. Use of collateral information to derive ratings has not been evaluated.

Disadvantages

• Lack of standardization which impairs inter-observer reliability (Beauchamp et al. 2001; Labi et al. 1998).

The Stages of Recovery: Loss of Consciousness

Q. Which part of the brain determines consciousness?

Answer

- Consciousness is a function of the ascending reticular activating system and the cerebral cortex.
- The cell bodies of the reticular activating system are located in the central reticular core of the upper brainstem (primarily midbrain) and connect to the cerebral cortex via thalamic and extra-thalamic projections.

Q. When does coma occur in TBI?

Answer

• When the reticular activating system cell bodies and/or enough of its cortical projections are disrupted by traumatic injury.

Q. Define coma in one sentence.

Answer

• It is a state of unconsciousness from which the patient cannot be aroused and there is no evidence of self- or environmental-awareness.

Q. Describe the clinical features of coma.

Answer

- No evidence of self- or environmental-awareness
- Eyes remain continuously closed
- No sleep-wake cycles on electroencephalogram
- No spontaneous purposeful movement
- Inability to discretely localize noxious stimuli
- No evidence of language comprehension or expression

Q. Describe how a Rancho Los Amigos-Level I patient typically presents.

Answer

• Persons at this level exhibit no observable change in behaviour when presented with stimuli and appear to be in a deep sleep.

The Stages of Recovery: Vegetative State

Q. Define the term vegetative state.

Answer

• Loss of capacity to interact with the environment despite the preserved potential for spontaneous or stimulus-induced arousal.

Q. Describe the clinical features of vegetative state.

Answer

- Patient opens eyes (either spontaneously or with noxious stimuli)
- Intermittent wakefulness with sleep-wake cycles
- No evidence of purposeful behaviour; may startle to verbal/auditory stimuli but will not localize
- No evidence of intelligible verbal or gestural communication
- Visual tracking is considered a sign of patient transitioning out of the vegetative state

Q. When is a patient deemed to be in a permanent vegetative state?

Answer

• Once the patient has remained in a persistent vegetative state for 3 months following non-TBI and 12 months following TBI.

Q. Describe how a Rancho Los Amigos-Level II patient typically presents.

Answer

• Persons at this level will respond to external stimuli with gross body movement, non-purposeful vocalization, and/or physiological changes (i.e., increased blood pressure/heart rate). The response may be slow, inconsistent, and/or delayed.

Stages of Recovery: Post-Traumatic Confusion and Amnesia

Q. Define the Minimally Conscious State.

Answer

• Severely altered consciousness with minimal but definite behavioural evidence of self- or environmental awareness.

Q. Describe the clinical features of the Minimally Conscious State.

Answer

- The patient demonstrates minimal evidence of self- and/or environmental-awareness.
- Purposeful movements are reproducible but remain inconsistent with respect to simple command following, object manipulation, and gestural or verbal yes/no responses.
- Eyes will open spontaneously.
- The patient may also show visual fixation, smooth pursuit tracking and emotional or motor behaviours contingent upon specific eliciting stimuli (i.e., patient may respond best to voices of family members).

Q. Describe how a Rancho Los Amigos-III patient typically presents.

Answer

- Persons at this level will be intermittently awake during the day.
- They will respond more specifically to stimuli (i.e., turn towards or away from a sound, follow moving objects within visual field, and withdraw from pain).
- They will follow simple commands and may respond inconsistently to simple questions using "yes" or "no" head movements.
- They will begin to recognize family and friends and may preferentially respond to them (Soares 2000).

Stages of Recovery: Post-Confusional Restoration of Cognitive Function

Q. How would a Rancho Los Amigos-Level IV typically present?

Answer

- Confused or frightened.
- Not able to understand what they feel, what is happening around them, or that people are trying to help them.
- Due to confusion, tend to over react to what they see, hear, or feel by hitting, screaming, thrashing about, or using abusive language may need to be restrained to avoid self-injury.
- Highly focused on their basic needs (i.e., eating, relieving pain, going to the bathroom, going home).
- Have difficulty following instructions not able to pay attention for even a few seconds.
- Will recognize family and friends some of the time.
- Able to do routine activities (i.e., feeding self, dressing, talking) with help (Soares 2000).

Q. How should a Rancho Los Amigos-Level IV patient be treated?

Answer

Treatment goals for Rancho Los Amigos-Level IV (Confused–Agitated) include:

- Decrease intensity, duration and frequency of agitation
- Increase attention to the environment
- Advance to a higher cognitive level

Treatment strategies include:

- Constant patient supervision
- Minimize noise and traffic within the patient's room
- Repeatedly attempt to orient the patient to place and time
- Offer physical reassurance by talking to and touching the patient (if he/she does not object to physical contact)
- Accommodation in a highly-structured setting
- Remove patient from the group or change the activity if agitation increases
- Freedom of movement should be provided to control outbursts
- Encourage simple self-care tasks and participation
- Psychotropic medications are used as a last resort (Soares 2000).

Rancho Los Amigos - Level IV - Confused-Agitated

A diagnosis of RLA - Level IV tells us the patient is alert but is not responding appropriately to the situation. There may be periods of agitation as the patient remains confused and frightened resulting in hitting, yelling, using abusive language, or screaming. Refusing to participate in activities is also common during this phase. To protect patients and to prevent them from hurting themselves it is not uncommon for them to be restrained. Patients may experience dense anterograde amnesia, they may be disoriented, have little recall of specific events, or have difficulty learning new information (Soares 2000).

Q. How would a Rancho Los Amigos-Level V patient typically present?

Answer

- Pays attention for a few minutes.
- Poor memory for information told to him/her since the injury and confabulates to fill in the gaps.
- Not oriented to place or time.
- Has difficulty making sense of the things going on around them.
- Easily becomes overloaded and restless when tired or exposed to stimuli.
- Not able to start or complete everyday activities (i.e., brushing teeth) even when physically able.
- Needs step-by-step instructions and requires help switching to the next part of the activity.

Rancho Los Amigos - Level V - Confused-Inappropriate

Patients in this stage of recovery are often better able to regulate their behaviour and focus their attention, although there may still be some episodes of confusion. Activities that the patient is asked to complete may need to be accompanied by step-by-step instructions. Memories of the injury or events that occur after the injury may be difficult to recall; however, memories related to events before the injury will be easily recalled. The patient may become focused on an activity and lack the ability to know when it is time to move on to something else. As the patient moves through this phase, cognition and behavioural functioning improve. The patient may be focused on their basic needs such as eating, toileting, or sleeping (Soares 2000).

Q. How would a Rancho Los Amigos-Level VI patient typically present?

Answer

- Memory and thinking problems resulting in ongoing confusion.
- Follows a schedule with assistance but easily confused by changes to the routine.
- Oriented to the month and year.
- Pays attention for approximately 30 minutes but easily distracted.
- Performs self-care activities (i.e., dressing, brushing teeth, eating) with assistance and knows when he/she needs to use the washroom.
- Knows he/she is hospitalized because of an injury but does not understand all of the problems he/she is having. Often there is more awareness of his/her physical rather than cognitive problems.

Rancho Los Amigos - Level VI - Confused-Appropriate

During this stage of recovery, patients can follow schedules set out for them but they still need some assistance and become confused by any changes. Individuals will be able to handle their own personal needs. Memory issues remain a problem and this is often apparent in their ability to remember they had a visitor but not remember why or what they did. Comprehension is often a serious problem as patients will be able to identify they are in a hospital but not understand why (Soares 2000).

Q. How would a Rancho Los Amigos-Level VII patient typically present?

Answer

- Follows a set schedule.
- Performs self-care activities independently.
- Has difficulty in new situations
- Thinks more slowly, becomes easily frustrated, and may act impulsively.
- Needs supervision because of poor judgement and insight.
- Thinking processes are inflexible and rigid.
- Does not fully appreciate how the cognitive problems will impact future plans (Soares 2000).

Q. How would a Rancho Los Amigos-Level VIII patient typically present?

Answer

- Understands that he/she has a problem with thinking/memory and begins to use compensatory strategies.
- Thinking processes are less rigid.
- Learns new things more slowly and becomes overloaded in difficult/stressful situations.
- Poor judgment is more apparent in new situations and requires assistance (Soares 2000).

Rancho Los Amigos - Level VII and VIII - Automatic-Appropriate and Purposeful-Appropriate

As patients move from RLA-VI to an RLA Level of VII you will see improvements in short term memory. Their behaviour will also be more appropriate to the situation and purposeful. Individuals will experience greater self-awareness and insight allowing them to achieve greater independence in selfcare and an ability to engage in unsupervised activities. RLA Level VIII is characterized by social competence and community re-entry. Patients often receive outpatient therapies, attend day programs, as well as participate in community re-entry and residential treatment programs. Tasks in this stage are designed to assist the individual in acquiring or attaining their self-directed goals (Soares 2000).

1.3 Focal Injury

Cortical Contusions

Q. What are cerebral contusions? Where do they tend to occur most often?

Answer

- Cerebral contusions are cortical bruises.
- They occur at the crests of gyri and extend to variable depths.
- They occur commonly at the inferior frontal, anterior temporal, and inferior occipital lobes (Burke & Ordia 2000).

Cortical contusions are quite common following TBI and in some cases can be quite involved, extending through the cortex and into the subcortical white matter (Burke & Ordia 2000). Cortical contusions tend to occur in characteristic areas, in part because of the movement of the brain in the skull with acceleration-deceleration and rotational forces, and because of the location of bony protrusions where the brain can strike inside the skull (Burke & Ordia 2000). One common combination of contusions is the coup-countrecoup injury. In this instance the patient strikes the front of their head and the brain accelerates forward in the direction of the impact striking the skull. The brain then rebounds in the opposite direction and strikes the back of the skull. Contusions usually occur bilaterally in the frontal poles, the anterior tips of the temporal lobes and in some cases the lateral parts of the temporal lobes and the occipital regions (Burke & Ordia 2000).



Figure 2. Coup-Contrecoup Injury

Intracranial Hemorrhages

Intracranial hemorrhage is a major concern post acquired brain injury, regardless of whether it is epidural, subdural, intracerebral, intraventricular, or subarachnoid in location (Burke & Ordia 2000). A hematoma can exasperate damage to the brain by placing direct pressure on the underlying brain structures or by causing a portion of the brain to herniate leading to secondary compression of the brainstem (Burke & Ordia 2000).

Intracranial Hemorrhages: Epidural Hematomas

Q. What is the general prognosis of epidural hematomas?

Answer

• The underlying brain injury is often not severe if treated promptly (Burke & Ordia2000).

Epidural hematomas (EDH) are often the result of an impact to the head that causes disruption of the middle meningeal artery and/or its branches (Ordia 2000). Less commonly an EDH can occur due to a dural venous sinus injury. Blood collects between the dura and the skull. On imaging, an EDH has a characteristic "lens-shaped" appearance that crosses the midline but does not cross the skull's suture lines. Symptom presentation can be delayed and may only become apparent 5 days post injury (Long 2013); however, if the EDH is related to an arterial laceration, it may evolve quickly resulting in rapid deterioration and even death (Burke & Ordia 2000). If treated promptly the underlying brain injury may not be that severe (Ordia 2000). Signs of an EDH include a decreased level of consciousness or

"clouding". If lesions occur in the frontal lobe, onset of symptoms may be slow and vague (Long 2013). Patients must be monitored carefully.



Figure 3. Epidural Hematoma

Intracranial Hemorrhages: Subdural Hematomas

Q. What is the general prognosis of subdural hematomas?

Answer

Prognosis is poor with a high mortality because of the severity of the underlying brain injury (Ordia 2000).

Subdural hematomas are common in severe brain trauma and often occur in individuals who are on blood thinners or who are older. They occur due to injuries of the cortical bridging veins or rarely the pial artery (Ordia 2000). On imaging, a subdural hematoma has a crescent shape that does not cross the midline (it is confined by dural reflections) but can cross skull suture lines. Due to the severity of injury to the underlying brain tissue, the prognosis is poor and mortality rates are high.

Figure 4. Subdural Hematoma

Intracranial Hemorrhages: Intracerebral Hemorrhage

Intracerebral hemorrhage may result from ruptured blood vessels in association with a penetrating or non-penetrating head injury. Although they often occur in the frontal or temporal lobes, they may also be found in the cerebellum and brain stem.

Figure 5. Intracerebral Hemorrhage

Intracranial Hemorrhages: Subarachnoid Hemorrhage

Subarachnoid hemorrhage (SAH) can be non-traumatic or traumatic in etiology. SAH most often occurs secondary to a ruptured aneurysm of the Circle of Willis causing blood to accumulate near the site of aneurysmal rupture. In contrast, SAH related to traumatic cerebral contusions is variable in terms of its location and is the result of microvessel shearing in the subarachnoid space. SAH can be associated with complications such as intraventricular haemorrhage, vasospasm, arachnoiditis, seizures, and communicating hydrocephalus because blood products obstruct the arachnoid granulations. Although rare, communicating hydrocephalus can progress to non-communicating hydrocephalus (Ordia 2000). SAH presents on computed tomography (CT) scan as bright hyperdense blood within the sulci and/or basal cisterns. CT is very sensitive for the detection of acute SAH. Magnetic resonance imaging is less sensitive for the detection of acute SAH, however is very good for identifying chronic blood products or hemosiderin deposits.

Figure 6. Cross-section of the brain: Subarachnoid Hemorrhage

Intracranial Hemorrhages: Intraventricular Hemorrhage

Intraventricular hemorrhage (IVH) can be classified as primary or secondary. Primary IVH occurs due to injury of the supependymal veins surrounding the ventricles. Secondary IVH occurs due to extension of adjacent SAH or intracerebral hemorrhage. On CT, IVH appears bright and is often layered within the dependent portions of the ventricles. IVH can obstruct CSF flow resulting in hydrocephalus.

1.4 Predictors of Outcome After TBI

Widely Used Indicators of Severity in Acute TBI

Q. List three widely used indicators of severity in acute TBI.

Answer

- Glasgow Coma Score (GCS; best score within 24 hours of injury)
- Duration of unconsciousness
- Duration of post-traumatic amnesia

The Glasgow Coma Scale

Q. Describe the Glasgow Coma Scale including its strengths and limitations.

Answer

Description

- The GCS is a quick, simple and objective tool used during the initial examination of level of consciousness to estimate TBI severity.
- The GCS consists of 15 items in three basic categories: (1) eye opening four items, (2) verbal response five items, and (3) motor response six items (Teasdale & Jennett 1974, 1976; Teasdale et al. 1978).
- Total summed scores range from 3 (totally un-responsiveness) to 15 (alert, fully responsive).
- Categorical divisions are used to differentiate patients in terms of initial severity of head injury such that GCS scores 13-15 represent mild injury, scores 9-12 represent moderate injury, and scores ≤8 represent severe injury (Sternbach 2000).

Advantages

- Simple, straightforward and brief bedside assessment.
- Most familiar and most widely used instrument in the assessment of level of consciousness.
- Established categories related to depth of coma and severity of injury.
- Significant predictor of outcome following head injury.
- Can be used by various groups of healthcare professionals regardless of level of education or intensive care unit experience.

Disadvantages

- The GCS is based on the assumption that evaluation of eye opening is sufficient to represent brainstem arousal systems activity.
- Assessment can be compromised by early interventions such as intubation and sedation.
- Use of a global score may result in loss of information that adversely affects the predictive accuracy of the GCS.
- The motor response subscore has the greatest influence on the total GCS score.
- Individuals with the same GCS scores in varying permutations can have significantly different survival outcomes.
- Lack of experience may result in inaccurate assessment.
- It is an ordinal scale whereby, for example, the difference between scores of 3 and 4 is not the same as the difference between scores of 13 and 14.

The Glasgow Coma Scale (GCS) was developed as a simple, objective assessment of impaired consciousness and coma which is based on eye opening, verbal and motor responsiveness (Teasdale & Jennett 1974, 1976). It has become the most widely known and widely used scale in the assessment of level of consciousness (Brain Trauma Foundation 2000; Hall 1997; Wade 1992). The GCS is an observer rating scale consisting of 15 items in three basic categories: 1) motor response (6 items), 2) verbal response (5 items), and 3) eye opening (4 items). Points are awarded for the best response in each category and category scores are summed to provide a global GCS score (Sternbach 2000; Wade 1992). Total summed scores range from 3 (totally un-responsiveness) to 15 (alert, fully responsive). A total of ≤8 is used to separate coma from non-coma (Wade 1992). Additional categorical divisions are used to differentiate patients in terms of initial severity of head injury such that GCS scores 13-15 represent mild injury, scores 9-12 represent moderate injury, and scores ≤8 represent severe injury (Sternbach 2000). The GCS is freely available, takes approximately 1 minute to administer and can be performed by all medical personnel (Oppenheim & Camins 1992). The test can be obtained at no cost at www.trauma.org/archive/scores/gcs.html.

Advantages

The Glasgow Coma Scale is a simple, straightforward and very brief bedside assessment. It is the most widely used instrument in the assessment of level of consciousness. GCS scores are a significant predictor of outcome following head injury; however, the prognostic value of the GCS is increased by taking other variables into account as well, such as mechanism of injury, age, CT findings, papillary abnormalities and episodes of hypoxia and hypotension (Balestreri et al. 2004; Demetriades et al. 2004; Zafonte et al. 1996).

Disadvantages

The GCS is based on the assumption that evaluation of eye opening is sufficient to represent brainstem arousal systems activity. While other assessments have been developed to provide a more comprehensive evaluation of brainstem responses, the resulting tools are substantially more complex than the GCS (Sternbach 2000).

The GCS has been reported to be reliable when used by various groups of healthcare professionals regardless of level of education or intensive care unit experience (Juarez & Lyons 1995). Nurses and general surgeons have been reported to be as consistent in their ratings as neurosurgeons (Teasdale et al. 1978). However, it has also been demonstrated that consistent ratings among inexperienced raters may also be inaccurate. Rowley and Fielding (1991) reported that the percentage agreement between inexperienced individuals and expert raters ranged from 58.3% to 83.3%. Lower levels of accuracy were most notable in the middle ranges of the scale. Training and the implementation of standard assessment procedures are important to maintain both high levels of reliability and accuracy of evaluation. The administration of a painful stimulus appears to be somewhat controversial and there is a great deal of variability in the means and location of its application (Edwards 2001; Lowry 1999).

The GCS is most often reported as a single overall score, although the scale authors did not recommend the summary score for use in clinical practice. While the single, global score may be a convenient way to summarize data, the use of a global score may result in a loss of information that adversely affects the predictive accuracy of the GCS (Healey et al. 2003; Teasdale et al. 1983; Teoh et al. 2000). The use of a global summary score assumes that each category is equally (Teasdale et al. 1983). However, it has been reported that motor response has the greatest influence on the summary score and results are skewed toward this component (Bhatty & Kapoor 1993). Healey et al. (2003) demonstrated that the ability of the GCS score to predict survival was derived mostly from the motor response category. In addition, the summary score represents a potential 120 combinations of scores from the three GCS components collapsed into only 13 possibilities. Different combinations of motor responsiveness, verbal responsiveness and eye-opening may have different associated outcomes. Teoh et al. (2000) reported significant differences in mortality outcomes between four of 11 scores with multiple permutations demonstrating that individuals with the same GCS scores in varying permutations can have significantly different risks for mortality.

Perhaps the most frequently encountered limitation of the GCS is untestable components in various patient groups. Pastorek et al. (2004) reported that the ability of the patient to be evaluated on the entire GCS contributed to the prediction of global outcome measures at 6 months (Pastorek et al. 2004). Unfortunately, patients who have been intubated or sedated, those with paralysis or facial swelling, patients with hypotension, hypoxia, alcohol or illicit drug intoxication all may not be able to provide responses to all categories of GCS items for reasons unrelated to head trauma (Demetriades et al. 2004; Oppenheim & Camins 1992; Rutledge et al. 1996). Murray et al. (1999) reported that in a study of head injury patients in European centres, total assessment was possible in 61% of patients before hospital, in 77% on arrival at hospital and in 56% of patients arriving at a neurosurgical unit. It has been suggested that inability to assess using the GCS may reflect the increased and more aggressive use of intubation, ventilation and sedation (Balestreri et al. 2004; Teasdale & Murray 2000). When the GCS was developed, the initial assessment was to be undertaken approximately 6 hours after injury to allow time for stabilization of systemic problems, but prior to the initiation of interventions such as neuromuscular paralyzing agents or sedatives (Bakay & Ward 1983; Marion & Carlier 1994). Increasingly, GCS assessment is performed upon arrival at the Emergency Department; some patients may be already intubated and/or sedated by that time (Marion & Carlier 1994; Waxman et al. 1991).

Q. Is the GCS predictive of outcome?

Answer

- Higher initial GCS scores tend to predict better recovery; however, prediction of prognosis and severity may be improved by considering the computed tomography scan results and other factors.
- Hypoxia and hypotension can decrease the GCS; therefore, GCS values after resuscitation from cardiopulmonary insults are more specific.
- Sedative medications can decrease GCS values and should be used only after full neurological evaluation (Koch 2007).

The GCS score has been shown to have a significant correlation with outcome following severe TBI, both as the summary score (Choi et al. 1994, Choi et al. 1988) and as the motor subscore (Beca et al. 1995; Bhatty & Kapoor 1993; Choi et al. 1988; Michaud et al. 1992).

In a prospective study by Narayan et al. (1981), the positive predictive value for a poor outcome (dead, vegetative, or severely disabled) was calculated to be 77% for patients with a GCS score of 3–5 and 26% for a GCS score of 6–8. As is commonly done, this study grouped GCS measurements versus outcome. In a larger study each GCS level would have its own predictive value. For example, in a series of 315 patients with TBI from Australia, a significant inverse correlation was demonstrated between the initial GCS score (obtained 6–48 hours after injury) and mortality (Fearnside et al. 1993).

In the United States, 746 patients with closed head injuries who were entered into the Traumatic Coma Data Bank were reviewed to determine the relationship of the initial GCS score with outcome (Marshall 1991). In this study, the interval from injury to outcome assessment was quite variable and ranged from 11 to 1,199 days, with a median of 674 days. The mortality rate for those with an initial post-traumatic GCS score of 3 was 78.4%; initial GCS score of 4, 55.9%; and initial GCS score of 5, 40.2%. Of note, however, is that 4.1%, 6.3%,

Table 2. Mort	ality Rates according to GCS
Scores	(Fearnside et al. 1993)

GCS Score	Mortality
3	65%
4	45%
5	35%
6	24%
7–13	10–15%

Table 3. 6-mont	h Mortality Rates according to
GCS Scores	Phuenpathom et al. 1993)

•		
Mortality		
100%		
90%		
63%		
33%		
22%		
0%		

and 12.2% of the three groups, respectively, had a good outcome. In a large study of 46,977 headinjured patients the relationship between GCS scores 3–15 and mortality was investigated (Gennarelli 1994). A sharp progressive increase in mortality was noted in patients who presented to the Emergency Room with a GCS score of 3–8. In 109 adults with acute subdural hematomas, Phuenpathom et al. (1993) also showed a significant inverse relationship with GCS score (best score within 24 hours) and mortality. In a series of 115 patients with EDH, Kuday et al. (1994) found that the initial GCS score was the single most important factor affecting outcome (p<0.00001).

Because of the strong association with the initial GCS score and outcomes, a number of investigators have studied the predictive value of the initial GCS score using various logistic regression techniques (Benzer et al. 1995; Hartley et al. 1995; Kaufmann et al. 1992; Stablein et al. 1980; Thatcher et al. 1991). Thatcher et al. (1991) used multimodal statistical models to study the ability of the initial GCS score or the GCS score obtained at a mean of 7.5 days after the injury to predict outcome at 1 year after injury for 162 patients with TBI. When based on the initial GCS score, only 68.6% of those predicted to have a good outcome and 76.5% of those predicted to have a poor outcome actually had such outcomes at 1 year. If the later GCS was used for predictions, there was a significant increase in the rate of correct predictions for a good outcome (80.6%), but the rate of correct predictions for a poor outcome remained essentially unchanged (78.6%). Kaufman et al. (1992) described the accuracy of outcome predictions of an experienced neurosurgeon for 100 patients with severe TBI. Outcomes were categorized as dead/vegetative, severely disabled, or capable of independent survival, and were predicted based on the best GCS scores obtained within 24 hours after injury. Age, pupils, blood pressure, heart rate, laboratory values, and initial CT scans were also considered. Correct prognosis was estimated in only 56% of the cases.

This table reveals that predictions were best for very bad or very good outcomes. In addition, poor outcomes were overestimated by 32–52%, while good outcomes were underestimated by 35%. It should be emphasized that most of these studies looked at the least discriminate scenario (e.g. reduction of potential outcomes to two or at most three groups).

Table 4. Glasgow Outcome Score and Neurosurgeon's Clinical Predictions vs. Actual Outcomes
(Kaufmann et al. 1992)

GOS	Clinical Prediction/Actual Outcomes		
Dead/Vegetative	35/24		
Severe Disability	23/11		
Independent	42/65		

When attempts were made to predict more precisely into one of the five categories of the Glasgow Outcome Scale (GOS), the predictive accuracy of the initial GCS score was poor (Jennett et al. 1976).

Duration of Unconsciousness

Duration of unconsciousness can be used to classify brain injury severity: <15–30 minutes = mild, 30 minutes –24 hours = moderate, 1–90 days = severe, >90 days = profound. Longer duration of coma is correlated with worse motor and cognitive recovery. In patients who remain in a coma for <2 weeks, severe disability remains an unlikely outcome. In contrast, those patients who remain in a coma for >2 weeks, good recovery is unlikely as 95% have moderate-severe disability as measured by the GOS.

Post-Traumatic Amnesia

Q. What is post-traumatic amnesia?

Answer

- Post-traumatic amnesia is determined by the duration of time from the point of injury until the patient has continuous memory of ongoing events.
- Resolution of post-traumatic amnesia clinically correlates with the period when incorporation of ongoing daily events occurs in the working memory.

Q. What is the significance of post-traumatic amnesia <24 hours?

Answer

- This is a TBI of mild to moderate severity.
- Can anticipate a quick and full recovery with appropriate management, although a few may show persisting disability.

Q. What is the significance of post-traumatic amnesia >4 weeks?

Answer

- This is a TBI of extremely severe severity.
- Can anticipate permanent deficits and significant disability; it is not just a matter of recovery but of long-term retraining and management.

Duration of Post-	Likely Outcome
Traumatic Amnesia	
1 day or less	Expect quick and full recovery with appropriate management (a few patients may show persisting disability)
More than 1 day and	Recovery period is more prolonged lasting weeks or months. However, for
less than 1 week	most patients full recovery is possible with good management
1–2 weeks	Recovery occurs over many months. Many patients will be left with residual
	problems even after the recovery process has ended, but one can be
	reasonably optimistic about functional recovery with good management
2–4 weeks	Process of recovery is very prolonged - 1 year or longer is not unusual.
	Permanent deficits are likely. There must be increasing pessimism about
	functional recovery when post-traumatic amnesia reaches these lengths
More than 4 weeks	Permanent deficits, indeed significant disability, are now certain. It is not just a
	matter of recovery but of long-term retraining and management

Table 5. Duration of Post-Traumatic Amnesia and Outcomes (Brooks & McKinlay 1989)

Duration of PTA has proportional relationship to coma duration (Brooks & McKinlay 1989):

- <5 minutes very mild
- 5–60 minutes mild
- 1–24 hours moderate
- 1–7 days severe
- 1–4 weeks very severe
- >4 weeks extremely severe

The Galveston Orientation and Amnesia Test

Q. Describe the Galveston Orientation and Amnesia Test including advantages and disadvantages.

Answer

Description

The Galveston Orientation and Amnesia Test consists of 10 items regarding orientation to:

- Person: name, address and birth date.
- Place: city/town and building they are in.
- Time: current time, date, month year and date of hospital admission.
- Memory of events both after and prior to the injury (Bode et al. 2000).

Advantages

- The Galveston Orientation and Amnesia Test provides an objective rating of early cognitive recovery eliminating the need for sometimes ambiguous terminology used to describe mental status, such as "confused" (Levin et al. 1979).
- Due to its design, the scale has been shown to be useful for assessing patients with a wide range of cognitive impairments.
- Can be used to guide timing of neuropsychological testing which should not be attempted until the patient's score is consistently >70.

Disadvantages

- The standard Galveston Orientation and Amnesia Test response format makes administration difficult with nonverbal patients (Novack et al. 2000); it is important to note that a multiple-choice version has been developed for use in aphasic patients but requires further evaluation.
- The requirement for oral or written expression may result in penalizing patients who are experiencing deficits of expression but not in orientation or in the retrieval or consolidation of memory (Jain et al. 2000).
- While the Galveston Orientation and Amnesia Test does contain items intended to provide an assessment of memory, it is primarily a measure of orientation; eight of the ten items evaluate orientation while only two examine memory (Forrester et al. 1994).

Q. What does a Galveston Orientation and Amnesia Test score of 75 mean?

Answer

- The Galveston Orientation and Amnesia Test is scored from 0 to 100; scores above 75 are within the range considered normal for the reference group (Levin et al. 1979; van Baalen et al. 2003).
- In order for a patient to be out of post-traumatic amnesia, the score must be above 75 on two consecutive administrations.

Assessment consists of 10 items regarding orientation to person (name, address and birthdate), place (city/town and building they are in) and time (current time, date, month, year and date of hospital admission) as well as memory of events both after and prior to the injury (Bode et al. 2000). Oral questions are posed directly to the patient who may respond either orally or in writing (Jain et al. 2000; Levin et al. 1979). Error points are awarded for each incorrect response and are summed and deducted from 100 to arrive at the total score. Both the scale and instructions for assigning error points are available in Levin et al. (1979).

The Galveston Orientation and Amnesia test (GOAT) was intended to evaluate orientation to time, place and person and to provide an estimation of the intervals prior to and following the injury for which there is no recall (Levin et al. 1979). The duration of PTA is defined as the period following coma in which the GOAT score is 75 or less (Levin et al. 1979). PTA is considered to have ended if a score greater than 75 is achieved on two consecutive administrations (Novack et al. 2000; Wade 1992; Zafonte et al. 1997). In the initial standardization study of Levin et al. (1979) using patients with mild head injury as a reference group, it was determined that a score of 75 represented a level achieved by 92% of the standardization group. No patients with mild head injury scored less than 65 on the GOAT. Scores between 66 and 75 are considered borderline-abnormal while scores above 75 fall into the range considered normal within the reference group (Levin et al. 1979; van Baalen et al. 2003).

The GOAT is a brief and simple mental status examination developed for use by healthcare professionals at the bedside or in the Emergency Department (Levin et al. 1979; van Baalen et al. 2003). It provides an objective assessment with a standardized cut-off for the presence of PTA. However, in its original form, the GOAT is not well suited to assessment of patients with aphasia. It may be too lengthy for a simple, repeated bedside assessment of mental status. However, it is freely available and can be used by any healthcare professional

Reliability		Validity		Responsiveness		
Rigor	Results	Rigor	Results	Rigor	Results	Floor/ceiling
	+++(TR)					
++	++(IO)	+	++	++	++	varied
	+++ (IC)					

Table 6.	The Galveston	Orientation an	d Amnesia Te	st Evaluation	Summary
		One near on an	a Annicala i C		Juilling

NOTE: +++=Excellent; ++=Adequate; +=Poor; N/A=Insufficient Information; TR=Test Re-test; IC=Internal Consistency; IO=Interobserver; varied (re. floor/ceiling effects; mixed results).

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