Systematic assessment of traumatic brain injury

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Abstract

Traumatic brain injury is time critical, which means it is essential that patients are assessed promptly and systematically using an approach such as ABCDE (airway, breathing, circulation, disability, exposure). Any existing or emerging abnormal physiological parameters must be identified and addressed to maintain adequate brain perfusion, thus limiting neurological cell death and minimising long-term disability. This article explains the pathophysiology of traumatic brain injury and discusses its systematic assessment using the ABCDE approach.

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In England and Wales, approximately 1.4 million people attend hospital each year with a traumatic brain injury (TBI), the most common cause of death under the age of 40 years (Lawrence et al 2016). [Q: how many of them die and how many survive? Could you please add figures here?] (The figures aren't precise as their cause of death could be a secondary event and its all dependant on what is noted on death certificate) Evidence suggests that children and people aged >65 years are particularly at risk of death following TBI, falls being the leading cause of initial injury in both groups (Levin and Diaz-Arrastia 2015).

Patients who survive a TBI may experience a wide range of long-term disabilities, from mild neurological symptoms to a persistent vegetative state. Common mild neurological disabilities following a TBI include cognitive decline and behavioural changes (Roozenbeek et al 2013). Symptoms may resolve over a period of 6-12 months, but some patients will experience symptoms for the rest of their life. Some will experience long-lasting mental health issues and many will experience chronic fatigue (Levin and Diaz-Arrastia 2015). These long-term consequences of TBI can negatively affect people's relationships and their ability to carry out daily activities including work. Because of the long-term disabilities experienced by patients who survive a TBI, prevention is crucial and nurses can contribute to it, for example by advising the public on road safety and risk of falls.

TBI is a time-critical injury. If a patient is admitted to hospital with a suspected TBI, prompt and systematic assessment is required to identify and address abnormal physiological parameters, maintain adequate brain perfusion, limit neurological cell death and minimise long-term disability. This article explains the pathophysiology of TBI and discusses its systematic assessment using the ABCDE (airway, breathing, circulation, disability, exposure) approach.

Pathophysiology

TBIs are sustained following a blow to the head with a sharp or blunt object, acceleration and deceleration injuries – such as whiplash in a car crash – or **rotational forces applied to the head such as a skiing or cycling accident** [Q: could you please give an example?]. These various forces cause bruising or bleeding of brain tissue.

The brain floats in the cranial cavity, suspended in cerebrospinal fluid (CSF), which makes it vulnerable to injury from forces travelling through its tissues. These may cause the brain to move violently within the cranial cavity, leading to shearing and tearing of neurones and/or blood vessels. If the head is hit by an object, the force can cause an injury directly under the point of impact (coup injury). Injury can also occur on the opposite side of the point of impact (contrecoup injury) (Rubin and Strayer 2012). For example, a blow to the front of the head could cause the brain to bounce off the occipital bone at the back of the head.

TBIs can be focal or diffuse. Focal TBIs affect a specific part of the brain following events such as skull fracture or focal haemorrhage. In diffuse TBIs, contusions are seen in multiple areas of the brain. Mortality rates differ between the two, focal and diffuse TBIs being fatal in 40% and 25% of cases, respectively (Zigmond et al 2015).

Injuries to the brain that occur as a result of the mechanisms described above can be divided into primary and secondary injuries. The event that caused the TBI – for example, a blow to the head – is regarded as the primary injury. It may cause bleeding between the meninges (membranes covering the brain and spinal cord) or directly into brain tissue. The developing haematoma causes damage to the tissue and prompts cerebral blood vessels to go into spasm (vasospasm), which interrupts blood flow (McCrory et al 2012). This leads to ischaemia and neurological cell death (Rubin and Strayer 2012).

The pathophysiology of the primary injury prompts a series of events that cause secondary injury. Secondary injury can develop between a few minutes and days after the primary injury (Kim and Gean 2011) and results from increased cerebral blood flow causing cerebral swelling. Increased cerebral blood flow, cerebral oedema and the developing haematoma produce a rise in intracranial pressure (ICP) (Kim and Gean 2011). This rise in ICP further hinders blood flow and oxygenation, leading to secondary brain injury. In the presence of a slowly developing haematoma, the ICP rises at a slower rate but eventually reaches a critical point. This can take a few hours and, in some cases, patients who had normal levels of consciousness and no significant signs of injury rapidly deteriorate (talk and die syndrome) (Levin and Diaz-Arrastia 2015).

History taking

It is vital that a thorough history is taken from patients presenting with a head injury and from any witness to preceding events. This enables the healthcare team to understand the circumstances of the injury, identify the forces involved and other injuries that may require attention, and prioritise care. Table 1 details the areas to enquire about during history taking.

Table 1. Areas to enquire about during history taking after head injury	
Information	**Rationale**
Name, address, date of birth, GP's name and address, preferred name	To access GP notes regarding past medical history, drug history and/or next of kin contacts. Knowing the patient's preferred name can assist in communicating effectively with them
First language	Patients who have sustained a brain injury are often more comfortable communicating, and at times will only be able to communicate, in their first language
Allergies	To protect the patient from exposure to allergens
Past medical history and family medical history	Conditions such as liver disease can increase the risk of bleeding following a TBI **and may or may not have caused the incident following a spontaneous cranial bleed** [Q: do you mean that TBI can be caused by a condition such as liver disease? Could you please explain this? Does this need to be explained in the section on pathophysiology?] (what I've added should clarify this point). Conditions such as chronic heart failure can lead to impaired oxygenation and

	circulation. Taking a family medical history may aid the identification of an undiagnosed condition
Drug history	Patients taking anticoagulants are at increased risk of bleeding that is challenging to control. Patients may be taking medicines that affect their level of consciousness. Taking a drug history can also aid in identifying pre-existing conditions
Last time the patient ate something	Needed in case the patient requires endotracheal intubation
Next of kin	A next of kin can support the patient and provide important information to the team. A next of kin would need to be contacted in case of rapid deterioration or to care for the patient upon discharge
Witness description of the event	To assist the healthcare team to understand the circumstances of the injury, identify the forces involved and identify other injuries that may require attention
Witness description of the level of consciousness immediately after the event until the time of admission	Witnesses can inform the team whether the patient has lost consciousness and for how long, or whether the patient's level of consciousness has been fluctuating. These reports can provide an indication of the forces involved and the potential for any secondary injuries. Furthermore, loss of consciousness is a one of the indications for CT scan. [Q: could you please add one sentence to explain rationale?]
Any pain immediately after and since the event	Determining the location, intensity and type of pain, whether pain is continuous or intermittent, whether it is associated with any visual disturbances, and whether it is radiating to other sites. This can indicate the site of impact or the potential for secondary injuries that would need addressing. [Q: could you please add one sentence to explain rationale?]
(Adapted from Innes et al 2018)	

If the patient is conscious, they may be able to provide some of the information detailed in Table 1. If the patient has an altered level of consciousness or is unconscious, it may be necessary to access their belongings for identification and/or next of kin contacts. Some people have an 'in case of emergency' (ICE) contact in their mobile phones. The police can be contacted to support identification and inform the next of kin. Police involvement may also be necessary if there is suspicion that a crime may have led to the event or if there is suspicion of safeguarding issues (National Institute for Health and Care Excellence (NICE) 2019).

Assessment

The ABCDE approach is a well documented assessment method that enables healthcare practitioners to identify and respond to life-threatening conditions in order of priority (Smith and Bowden 2017, **Resuscitation Council (UK) 2020** [Q: added reference citation OK?]) (yes, thank you). It is important to note that, in TBI, there may be major trauma and that catastrophic bleeding may need to be controlled before proceeding to airway assessment. In such cases, the acronym ABCDE is modified to C-ABCDE (Smith and Bowden 2017) – **the 'C' standing for 'catastrophic' bleeding** [Q: addition correct?] (yes, thank you).

Airway

Any patient with an actual or suspected TBI is at significant risk of altered level of consciousness, which can lead to compromised airway. As the level of consciousness decreases, airway muscles relax, causing the mandible to fall backwards and the tongue to obstruct the airway; the relaxed oropharyngeal wall also obstructs the airway. Furthermore, protective airway reflexes such as cough, gag and swallow are blunted, causing a significant risk of pulmonary aspiration of secretions or gastric content (Dolan and Holt 2013).

The airway should be assessed by using a 'look and listen' approach. Looking into the airway enables the nurse to detect the presence of foreign objects, loose teeth, signs of trauma, gastric content or excess saliva (Resuscitation Council (UK) 2016). Any bodily fluids should be suctioned using a Yankauer suction tip, taking care not to cause trauma. Listening to the airway enables the nurse to detect obstruction: snoring noises suggest a partially obstructed airway while a silent airway suggests complete obstruction. Any airway obstruction should be immediately addressed, as it will hinder breathing and therefore oxygenation.

TBI can complicate airway management because it is often accompanied by facial injuries and/or suspected cervical spine injury. The presence of a cervical spine injury should be assumed until excluded **by either X-ray, computed tomography (CT) and/or physical examination** [Q: are all three needed to exclude cervical spine injury?] (Farag 2016). If cervical spine

injury has been excluded, the 'head tilt-chin lift' manoeuvre can be used to open the airway and maintain it open. If the airway needs to be supported, the nurse can use the 'jaw thrust' technique, where the jaw is lifted forwards using its angle (Prasarn et al 2014). **A medical device called an airway adjunct can be used to maintain the airway open. An oropharyngeal airway (Guedel airway) is usually appropriate. A nasopharyngeal airway should not be used in actual or suspected TBI because of the high risk of base-of-skull fracture, which means the nasopharyngeal airway tube could inadvertently be inserted into the brain via the fracture** [Q: correct as edited?] (yes, thank you). (Resuscitation Council (UK) 2016).

Any of following requires immediate intubation **and ventilation** [Q: added as per NICE 2019; OK?] (yes, thank you). (NICE 2019):

» Glasgow Coma Scale (GCS) score of ≤8.

» Loss of protective **laryngeal** [Q: amended as per NICE 2019; OK?] (yes, thank you). reflexes.

» Partial pressure of oxygen (PaO_2) <13kPa on oxygen or partial pressure of carbon dioxide ($PaCO_2$) >6kPa.

» Spontaneous hyperventilation causing $PaCO_2$ <4kPa.

» Irregular respirations.

Breathing

A 'look and listen' approach is also used to assess breathing. The nurse will look at the patient's breathing to ascertain the work of breathing – that is, how much effort is involved. The use of accessory muscles indicates a greater effort and suggests potential airway issues or hypoxia, since respiratory rate and depth are partly controlled by chemoreceptors that are sensitive to changes in arterial oxygen tension (Lumb 2016).

The nurse will check that both sides of the chest are rising equally on inspiration (bilateral chest rise). Unilateral chest rise could indicate a pneumothorax, which would significantly hinder gas exchange and circulation (Mulryan 2011). A pneumothorax is a leading cause of cardiac arrest. If it is suspected, the cardiac arrest team should be called immediately.

The respiratory rate should be counted for a full minute – a normal respiratory rate is considered to be 12-20 breaths per minute. At the same time, the rhythm of breathing should be noted. A significant rise in ICP can cause pressure on the respiratory centres in the pons and medulla oblongata, leading to abnormal breathing patterns (Selladurai and Reilly 2007).

The nurse will observe the patient's colour. Central cyanosis, identifiable by a blue hue on the lips and skin, is a late sign of hypoxia. For patients with darker skin, the nurse will look at the **mucous membranes inside the mouth** [Q: what colour should they be?] or pull down the lower eyelid to observe the **palpebral conjunctiva** [Q: what colour should it be?] to assess for a blue hue which indicates cyanosis.

The nurse will listen for any added sounds during breathing. An expiratory wheeze suggests lower airway obstruction, while an inspiratory wheeze suggests upper airway obstruction (Resuscitation Council (UK) 2016). Gurgling noises can indicate fluid in the airway that would need to be suctioned to avoid aspiration, while a crackling noise on breathing can indicate pulmonary oedema, which would significantly impair oxygenation (Innes et al 2018). [Q: please add a reference citation for the last sentence].

It is essential to address any oxygenation issues, since inadequate cerebral oxygenation is an independent indicator of suboptimal outcome in TBI (Rosenfeld et al 2012). Arterial blood gas measurements should be used to guide decisions about oxygen therapy, and oxygen saturation of haemoglobin should be measured using a pulse oximeter. Oxygen therapy needs to be prescribed and administered to achieve and maintain oxygen saturations of 94-98% (British Thoracic Society 2017). In severe cases, an arterial line may need to be inserted to enable regular arterial blood gas analysis. [Q: there were two separate paragraphs about arterial blood gases and oxygen therapy; they have been merged into one for clarity; correct as edited?] (yes, thank you)

Circulation

Maintaining sufficient circulation is essential to ensure the brain receives adequate oxygen and nutrients via the blood (cerebral perfusion), so circulation must be assessed and any abnormalities in circulatory function addressed. Many patients with a severe TBI may have other injuries causing haemorrhage, which will make it challenging to maintain adequate circulation. Any bleeding points must therefore be promptly assessed and treated to stop further blood loss.

Assessing circulation involves a 'look, listen and feel' approach. The nurse will look at the patient's **pallor** [Q: should this be 'skin colour' or 'complexion'?] (yes, thank you); **pale pallor** [Q: should this be simply 'pallor'?] (yes, thank you) indicates circulatory shutdown, as physiological compensatory mechanisms shunt blood to essential organs. In patients with darker skin, the nurse will assess the mucous membranes, which will be pale in case of circulatory shutdown (Creed and Spiers 2010).

The nurse will feel the patient's peripheral temperature by touching their hands and feet. Cold peripheries indicate peripheral circulatory shutdown.

Capillary refill time (CRT) should be assessed by pressing a finger on the sternum for 5 seconds and releasing it to see how quickly the colour returns. The CRT should be ≤3 seconds (Resuscitation Council (UK) 2016).

The peripheral pulse should be assessed at the radial artery, counting for one minute while also assessing its rhythm and quality. A thready pulse (where the magnitude changes with each pulse) is a strong indicator of hypovolaemia, which could result from major cerebral bleeding or traumatic injuries elsewhere (Selladurai and Reilly 2007). Furthermore, a rise in ICP can damage the brainstem, which can lead to abnormal cardiac rhythms such as bradycardia or tachycardia. It is therefore advisable to record a 12-lead electrocardiogram (ECG).

Listening [Q: should this be 'Feeling'?] (Korotkoff sounds are listened to by stethoscope) also involves measuring blood pressure. If the patient is in atrial fibrillation, characterised by an irregular pulse, blood pressure should be measured manually every time because electronic non-invasive blood pressure measurements are inaccurate in atrial fibrillation (Lister et al 2020).

If the patient is hypovolaemic, systolic blood pressure may be low and this should be addressed by administering normal saline (Haddad and Arabi 2012). Recommendations are that systolic blood pressure should be maintained at >100mmHg in patients aged 50-69 years and at >110mmHg in patients aged 15-49 years and patients aged ≥70 years (Carney et al 2017). Local guidelines should be followed.

A rise in ICP causes brainstem damage, leading to abnormal functioning of the cardiac centre. This can result in patients presenting with hypotension, normotension or hypertension (Selladurai and Reilly 2007).

In addition to the above assessments, blood samples should be taken to determine full blood count, coagulation, urea and electrolytes, liver function and blood group. The rationale for blood tests in TBI is detailed in Table 2.

Table 2. Rationale for blood tests in traumatic brain injury	
Blood test	**Rationale**
Full blood count	» To check that haemoglobin levels are sufficient to ensure efficient oxygen carriage to the brain » To check for haemorrhage and/or determine the need for blood transfusion » White blood cell count indicates existing or developing infections, **which are a particular risk in open or penetrating traumatic brain injury** [Q: correct as edited?] (yes, thank you) » To check haematocrit – normal haematocrit will ensure optimal blood viscosity, thereby facilitating blood flow to the brain
Coagulation	» To identify potential coagulopathies » To identify potential anticoagulant therapy, which will require reversing if the patient is bleeding
Urea and electrolytes	» To assess renal function » To identify potential traumatic renal injury or ischaemic injury if the patient has been hypotensive for a long period
Liver function	To check liver function, which may be suboptimal in patients with alcohol addiction or abdominal trauma. Liver conditions can lead to coagulation issues, since clotting factors are synthesised in the liver
Cross match	To determine the patient's blood group should they require transfusion of blood or blood products
(Adapted from Selladurai and Reilly 2007, NICE 2019)	

Disability

Under 'disability', the nurse will assess the patient's neurological status and other elements that may influence their level of consciousness. At all previous stages of the ABCDE assessment, the nurse will have attempted to communicate with the patient, so they will already have a clear idea of the patient's level of consciousness, but this still needs to be formally assessed. A quick and easy way to do this is by using the AVPUC acronym (Smith and Bowden 2017), which stands for:

» **A**lert.

» Responds only to **V**oice.

» Responds to **P**ain.

» Is **U**nresponsive.

» New or recent **C**onfusion or delirium.

The patient's serum blood glucose level can affect their level of consciousness, so a point-of-care test is imperative to rule out or correct hypo- or hyperglycaemia.

The level of consciousness is most commonly evaluated using the GCS, detailed in Table 3. A GCS score >12 indicates a mild TBI, a GCS score of 9-12 indicates a moderate TBI and a CGS score ≤8 indicates a severe TBI (NICE 2019).

Table 3. Glasgow Coma Scale		
Element	Response	Score
Eye opening	Open spontaneously	4
	Open to sound	3
	Open to pain	2
	Do not open	1
Best verbal response	Orientated to time, place and person	5
	Confused	4
	Inappropriate responses	3
	Incomprehensible sounds	2
	No response	1
Best motor response	Obeys commands for movement	6
	Movement to localised pain stimulus	5
	Normal flexion withdrawal from pain	4
	Abnormal flexion withdrawal from pain	3
	Abnormal extension withdrawal from pain	2
	No response	1
(Adapted from Teasdale et al 2014)		

Lack of experience or inadequate training in the use of the GCS can lead to inconsistent scoring, with research suggesting that the motor response element of the scale is the most inaccurately assessed (Namiki et al 2011). It is imperative that the patient is assessed by a healthcare practitioner competent in using the GCS. Changes in GCS scores should be reported immediately to the consultant or a senior member of the team caring for the patient, as it could signify deterioration.

The following paragraphs explain how to interpret a patient's responses when assessing consciousness using the GCS. They need to be read in conjunction with Table 1.

Eye opening

In a normal state of consciousness, eye opening should be spontaneous. With altered levels of consciousness, the patient may open their eyes to sounds or speech – but maybe only speech in their first language – or to pain. Inducing pain to assess eye opening is achieved by exerting graduated pressure on the nail bed, supraorbital notch or trapezius notch (Figure 1a, 1b and 1c), but exerting pressure on the supraorbital notch is not recommended in case of facial injuries. Sternal rub is no longer acceptable as a way of inducing pain because of the risk of soft tissue trauma.

Figure 1a, 1b, 1c. Exerting pressure on the nail bed, supraorbital notch and trapezius notch
[Supplied by author. Permission to use, including written permission from the patient, to come from author]

Best verbal response

An orientated patient should be able to vocalise their name, the time of day and place. If one of these is incorrect, the patient is considered confused (Middleton 2012). 'Inappropriate responses' mean that the patient is not forming comprehensible sentences or is saying random words. 'Incomprehensible sounds' refer to sounds such as groans or moans. 'No response' means no verbal response of any kind, including sounds (Middleton 2012).

Best motor response

'Obeys commands for movement' means the patient is able to follow commands such as 'lift your arms' or 'wriggle your fingers and toes'. 'Movement to a localised pain stimulus' occurs when the patient reaches, without being asked to, for an area where graduated pressure is being exerted (Figure 2). A patient demonstrating 'normal flexion withdrawal from pain' will withdraw from a pressure stimulus on the nail bed (Figure 3). An 'abnormal flexion withdrawal from pain' will cause the patient to flex their arms towards their chest, flex their wrists, form fists with their hands, and rotate their legs inwards (Figure 4). An 'abnormal extension withdrawal from pain' will cause the patient to extend their arms, flex their wrists, extend their legs and rotate their feet inwards. They may also clench their teeth and extend their neck (Figure 5). If the patient responds on one side of the body only, **this still counts as a valid motor response for their GCS score and is rated the same as a bilateral response** [Q: correct as edited?] (Its classed as 'best motor response') (Middleton 2012).

Figure 2. Movement to localised pain stimulus
Figure 3. Normal flexion withdrawal from pain
Figure 4. Abnormal flexion withdrawal from pain
Figure 5. Abnormal extension withdrawal from pain
[Supplied by author. Permission to use, including written permission from the patient, to come from author]

Pupillary response to light

Although this is not part of the GCS, the patient's pupils should be assessed for their response to light. Each pupil should constrict in response to a bright light being shone at the eye. The nurse will note the size of each pupil before and after shining a light at each eye. Normal pupils are equal in size and reactive to light. Significant asymmetry indicates a developing cerebral mass such as a haematoma (Selladurai and Reilly 2007). Pupillary abnormalities or changes should be noted and reported immediately. Table 4 shows how to interpret different pupillary responses to light.

Table 4. Pupillary responses to light	
Pupillary response	**Interpretation**
Equal in size and reactive to light	Normal response
Dilated and non-reactive to light	Suggests third cranial nerve compression following brainstem herniation due to raised intracranial pressure. Potential ocular or orbital injury
Bilateral dilated and non-reactive	Suggests upper brainstem damage – but drugs such as atropine sulfate and barbiturates can cause dilation of the pupils
Normal size and fixed	Suggests midbrain injury
Oval	Suggests early stages of brainstem herniation due to raised intracranial pressure
(Adapted from Selladurai and Reilly 2007)	

Exposure

Under 'exposure', the nurse will assess the patient for injuries or wounds that could be a cause for concern. It is important to assess the patient's front and back and to pay attention to the head, where hair may cover wounds or bruising. The abdomen should be assessed for signs of distension that could signify internal bleeding. Any areas that has received an impact during the traumatic event should be carefully assessed. Skin rash and evidence of intravenous drug injection should be noted, as well as old bruising, which could be significant in a safeguarding investigation. **It may be appropriate to**

request medical illustrations attend when the patient is stable to document any issues. These photographs could form evidence in any subsequent safeguarding or criminal investigation. [Q: could you please clarify the meaning here?].

Intravenous access secured, and dressings applied, in the pre-hospital setting should be assessed, as they could be a focus of infection and induce a risk of sepsis. Any redness, swelling or oozing should be noted.

In some cases, the patient's ability to thermoregulate is impaired due to damage to thermoregulation centres in the brain and the patient can become hypo- or hyperthermic. Temperature should therefore be recorded and abnormalities addressed and managed (Mrozek et al 2012). Evidence suggests that an abnormal core temperature is associated with a less favourable outcome **in TBI** [Q: addition correct?] (yes, thank you) (Haddad and Arabi 2012).

Ongoing assessment and care

After the initial assessment and once identified issues have been addressed, the patient **must be regularly reassessed using the ABCDE approach.** [Q: using the same process as described above?] How often is a matter of clinical judgement, but it is important that the patient is reassessed whenever there is a change in their condition so that treatment can be adapted. Treatment and care should follow recognised local and national guidelines, such as those provided by NICE (2019) for England and Wales. Evidence suggests that adherence to local guidelines improves outcomes for patients with TBI (Gerber et al 2013).

Conclusion

TBI can affect people of any age and even a mild TBI can induce long-term neurological disabilities, so prevention is crucial. When a patient presents with a suspected TBI, prompt and systematic assessment with an approach such as ABCDE is of essence. It enables the healthcare team to identify physiological changes and prioritise interventions, maintain adequate brain perfusion, limit neurological cell death and minimise long-term disability. Reassessing patients on a regular basis enables the team to detect changes in the patient's condition, adjust treatment accordingly and prevent further brain injury.

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