Neuromonitoring

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Abstract

Management of acute brain injury is based on a central concept that prevention of secondary hypoxic/ischaemic injury is associated with improved outcomes. While clinical assessment of neurological state remains fundamental to neuromonitoring, several techniques are available for global and regional brain monitoring that provide assessment of cerebral perfusion, oxygenation and metabolic status, and early warning of impending brain hypoxia/ischaemia. Developments in multimodality monitoring have enabled an individually tailored approach to patient management in which treatment decisions are guided by monitored changes in physiological variables rather than pre-defined, generic thresholds. Any impact of monitor-guided therapy on outcomes is entirely dependent on the threshold to initiative intervention and subsequent management in response to change in a particular monitored variable, and these remain undefined in many circumstances. This review describes current neuromonitoring techniques used during the critical care management of acute brain injury.

Keywords Cerebral autoregulation; cerebral microdialysis; cerebral oxygenation; electroencephalography; intracranial pressure; multimodal neuromonitoring; near infrared spectroscopy; neurointensive care

Royal College of Anaesthetists CPD Matrix: 2A04, 2F01, 3C00, 3F00

Learning objectives

After reading this article, you should be able to:

- identify the key intracranial physiological variables that can be monitored at the bedside
- understand the advantages and limitations of different neuromonitoring techniques
- understand the use of multimodality monitoring to guide individualized management in a critically ill brain-injured patient

Acute brain injury (ABI) management is based on the central concept that prevention of secondary hypoxic/ischaemic injury is associated with improved outcomes. Optimization of cerebral perfusion, oxygenation and metabolic status is therefore fundamental to the critical care management of ABI. Neuromonitoring allows assessment of multiple aspects of cerebral physiology, early detection of abnormalities and assessment of response to treatment, and can be used to guide individualized treatment strategies to minimize the risk of secondary hypoxic/ischaemic injury.[1,2] Several neuromonitoring techniques may be applied in clinical practice; some are widely available and well-established, whereas others are more novel and less well developed (Table 1). The Neurocritical Care Society and European Society of Intensive Care Medicine have published consensus guidelines for the use of multimodality neuromonitoring.[3]

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Clinical examination

Clinical neurological assessment remains the cornerstone of neuromonitoring. The Glasgow Coma Scale (GCS) is an easy-to-use instrument for evaluating neurological status by recording best eye opening and verbal and motor responses to standardized verbal and physical stimuli (Box 1).[4] It provides a global assessment of consciousness, and identifies changes in neurological state by means of serial recording. Sedation and mechanical ventilation, while a mainstay of treatment in ABI, confound the assessment of GCS score, and reduced intracranial compliance precludes sedation holds for neurological assessment. The main limitations of the GCS are that verbal responses are not assessable in intubated patients, brainstem function is not directly considered, and GCS 3 may cover a spectrum of brain injury severity. To overcome some of the problems, alternative scoring systems such as the Full Outline of UnResponsiveness (FOUR) score have been developed, but experience with them is limited compared with the GCS.[3] GCS is a global measure so it is important also to identify and document focal neurological deficits (limb weakness) and pupil responses. Infrared pupillometry provides an objective assessment of pupillary reactivity and may be superior to clinical assessment.[1]

Intracranial pressure

Two methods of monitoring intracranial pressure (ICP) are commonly used in clinical practice—ventricular catheters or micro-transducer systems (strain gauge or fibreoptic types).[5] Ventricular catheters are considered the gold standard as they measure global ICP. Advantages also include the possibility for recalibration during use and drainage of cerebrospinal fluid to treat intracranial hypertension. Ventricular catheters are associated with greater risks compared to micro-transducer devices, including intracranial haemorrhage, seizures and catheter-associated ventriculitis. Microtransducer devices are usually placed into brain parenchyma via a cranial access device, although subdural placement after craniotomy is an option. They measure localized ICP, but this correlates with ventricular pressure in most circumstances. The complication rate of intraparenchymal microtransducer devices, including infection, is very low. Although recalibration is not possible, zero drift is insignificant over the course of their clinical utility.

ICP monitoring guides targeted management to prevent or treat intracranial hypertension and allows monitoring and

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Advantages and disadvantages of bedside neuromonitoring techniques

Technique	Advantages	Disadvantages
Intracranial pressure		
Ventricular catheter	• Gold standard • Measures global pressure • Therapeutic drainage of cerebrospinal fluid • *In-vivo* calibration	• Placement technically difficult • Risk of haemorrhage • Risk of infection
Microsensor	• Intraparenchymal/subdural placement • Easy to place with low procedural complication rate • Low infection risk	• *In-vivo* calibration not possible • Measures localized pressure
Transcranial Doppler	• Non-invasive • Real time with good temporal resolution	• Measures relative rather than absolute cerebral blood flow (CBF) • Operator dependent • Failure rate of 5—10% (absent acoustic window)
Jugular venous oximetry	• Assesses balance between oxygen delivery (blood flow) and demand (metabolism) • Easy to perform	• Global and insensitive to regional changes • Risk of vein thrombosis, haematoma, carotid puncture
Brain tissue pO_2	• Bedside gold standard for brain oxygenation monitoring • Assesses balance between oxygen delivery (CBF) and demand (metabolism) • Continuous	• Invasive • Measures regional oxygen tension so utility dependent on probe location
Near infrared spectroscopy	• Non-invasive • Real time • Assessment of regional cerebral oxygenation over multiple regions of interest	• Dependent on manufacturers algorithms • Signals affected by extracerebral tissue
Microdialysis	• Measurement of local brain tissue biochemistry • Early detection of hypoxic/ischaemic injury • Monitor of cellular bioenergetic distress	• Focal measure • Thresholds for abnormality uncertain
Electroencephalography	• Non-invasive • Real time • Correlates with ischaemic and metabolic changes • Assessment of non-convulsive seizures/status epilepticus	• Skilled interpretation required • Affected by anaesthetic/sedative agents

Table 1

management of cerebral perfusion pressure (CPP) which is calculated as the difference between mean arterial blood pressure and ICP. For the accurate calculation of CPP, the arterial pressure transducer must be referenced at the same level as ICP (tragus of the ear).[5]

ICP monitoring is recommended in the management of severe traumatic brain injury (TBI) and increasingly used in other brain injury types, particularly poor grade aneurysmal subarachnoid haemorrhage (SAH).[1] However, its ubiquity is not supported by clear evidence of improved outcomes from monitored-guided treatment strategies. A recent randomized controlled trial did not identify any difference in 6-month outcomes after TBI between patients randomized to management guided by ICP monitoring compared to clinical and radiological assessment in the absence of ICP monitoring. Because both treatment approaches provided satisfactory outcomes despite the absence of ICP monitoring in one, the results of this study challenge the established practice of maintaining ICP below a universal and arbitrary threshold. Individualized interpretation of ICP in association with other monitored variables might identify circumstances in which modestly elevated ICP might be cautiously accepted. One area of uncertainty is what, if any, action should be taken in response to increases in ICP in the context of normal brain oxygenation.[5]

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