Advances in Cerebral Monitoring for the Patient with Traumatic Brain Injury

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KEYWORDS

- Multimodal monitoring • Neurocritical care • Intensive care • Nursing
- Traumatic brain injury

KEY POINTS

- For patients with traumatic brain injury (TBI), the future of multimodal monitoring (MMM) has yet to be fully realized.
- The past 2 decades have witnessed significant technological advances that now make it possible to simultaneously monitor the physical, chemical, and electrical activity inside the skull.
- High temporal-resolution monitors are quickly replacing static "moment-in-time" measures; global cerebral monitoring is giving way to regional and even localized monitors.
- The elusive Holy Grail of MMM is a single integrated system that will provide clinicians with highly reliable and valid measures, which will guide decisions that lead to improve patient outcomes.

INTRODUCTION

The fully functional human brain relies on the complex interplay of physical, chemical, and electrical pathways. Injury along any one neurologic pathway may be noted as a change in neurologic function. Patients with traumatic brain injury (TBI) are at high risk for injury to one or more parts of multiple pathways. This gives rise to the concept that a comprehensive critical care TBI program is one that provides practitioners with a wide variety of tools to simultaneously monitor multiple parameters associated with neurologic function. The phrase multimodal monitoring (MMM) describes this dynamic process.

The primary TBI event triggers a wide host of chemical, electrical, and mechanical pathways that result in tissue damage and give rise to secondary brain injury. The secondary brain injury inflammatory cascade is a common pathway that includes

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blood-brain barrier (BBB) disruption, generation of free radical oxygen species, migration of microglia and macrophages, thrombin-mediated effects, and inflammatory cytokines. An understanding of the parameters available to monitor for secondary brain injury is essential to manage patients in the neurocritical care unit (NCCU).

Following TBI, the 3 primary reasons for monitoring the brain are as follows:

1. To provide an early warning, which allows for an opportunity for intervention with treatment or additional monitoring if indicated,
2. To evaluate the impact of ongoing treatment, and
3. To prognosticate patient outcome.

Monitoring multiple parameters provides the clinician with both an early warning when the patient is deteriorating and data to evaluate the effectiveness of interventions. Finally, MMM provides prognostic data. This article serves to familiarize the readers with the most common MMM tools by dividing the discussion into the most common noninvasive and invasive types of monitoring that are currently used in the practice of caring for patients with TBI.

NONINVASIVE MONITORING

A "noninvasive" cerebral monitoring device does not require invasion of the protective barriers, including skin, skull, or dura. Although both invasive and noninvasive monitoring may require significant resources, the latter is attractive because of faster setup times and lower risk of infection. The primary modes of MMM in the NCCU, discussed in the following sections, are the neurologic examination, neuroimaging, ultrasound, near-infrared spectroscopy, and electrophysiological monitoring.

The Neurologic Examination

Despite significant technological advances in health care, the most efficient method of monitoring patients with TBI is performing a neurologic examination based on the history.[1,2] The history provides the examiner with clues to the mechanism of injury and potential complications.[3] The physical examination allows the practitioner to formulate treatment decisions and to assess the need for additional monitoring.[2] At a minimum, the examination should assess the level of consciousness, cranial nerves, motor examination, sensory level, and vital signs.[1]

Level of consciousness is dependent on the arousal and cognitive components derived from the reticular activating system and cerebral cortex and is graded by the awareness of self in relation to the environment.[4,5] Consciousness, evaluated in terms of eye opening, verbal assessment, and motor examination, may be scored using the Glasgow Coma Scale (GCS) or the Full Outline of Unresponsiveness (FOUR) score.[6,7] The GCS, which ranges from 3 to 15, was designed to measure the initial severity of TBI. A GCS less than or equal to 8 is typically used as a threshold to define the need for airway protection (intubation and mechanical ventilation).[8] The FOUR score, which ranges from 0 to 16, is similar to the GCS, but includes brainstem reflexes and respiratory pattern instead of the verbal component of the GCS.[9]

Pupillometer

A key element of the physical examination is the cranial nerve (CN) assessment. Assessing pupillary function examines components of CN-II (optic) and CN-III (oculomotor). The traditional method of pupillary examination, using a handheld flashlight to subjectively score the size, shape, and reactivity of the pupils, has limited interrater reliability.[10] The pupillometer is a handheld device that works by first measuring the

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