Archives of Medicine©
14 (12) 2022 : 001-003 • MINI REVIEW

Children with acute brain injury undergoing multimodal neurologic monitoring

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SUMMARY

Acute neurologic illness has a high mortality and neurologic disability risk for children. Cerebral hypoxia, hypoperfusion, and edema frequently exacerbate severe traumatic brain injury, cardiac arrest, stroke, and central nervous system infection, resulting in additional neurologic damage and worse outcomes. The management of these conditions places an emphasis on close physiologic monitoring and supportive care due to the lack of targeted neuroprotective therapies. In this review, we will focus on the physiologic concepts behind each tool and discuss advanced neurologic monitoring strategies for pediatric acute neurologic illness. New monitoring methods and the use of neurologic monitoring in critically ill patients at risk of neurologic sequelae will also be highlighted in this article.

Keywords: Intracranial pressure; Cerebral autoregulation; Traumatic brain injury; Hypoxic-ischemic; Brain injury.

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Word count: 1043 **Tables:** 00 **Figures:** 00 **References:** 10

Received: 01.12.2022, Manuscript No. ipaom-22-13364; **Editor assigned:** 03.12.2022, PreQC No. P-13364; **Reviewed:** 15. 12.2022, QC No. Q-13364; **Revised:** 20.12.2022, Manuscript No. R-13364; **Published:** 27. 12.2022

INTRODUCTION

Children with acute neurologic illness have a high mortality and morbidity rate. Over half of children with normal baseline neurological function who suffer an acute neurologic insult develop adverse neurologic outcomes. Neuroprotective strategies address the causes of "secondary" brain injury (such as cerebral edema and ischemia) because there are few targeted therapies. Maintaining cerebral perfusion and oxygenation while anticipating and addressing pathologic increases in intracranial pressure (ICP) are key components of critical care for children with acute neurological injuries. Based on physiologic principles, such as intracranial compliance and cerebral autoregulation, these children require extensive monitoring [1,2].

DESCRIPTION

Due to the limited neurologic examination, prognostication of outcome presents a significant challenge in pediatric critical care. Pharmacologic agents (such as sedatives and neuromuscular blockades), metabolic abnormalities, and the child's developmental stage, for instance, can muddle the examination after cardiac arrest. Poor outcomes have been linked in small pediatric studies to the absence of motor response, a Glasgow Coma Scale (GCS) score below 5, the absence of spontaneous respiratory effort, and nonreactive pupils 24 hours after return of circulation. Neurologic monitoring technologies have emerged to provide multimodal pathophysiology assessment, direct intervention, and enhance prognosis in light of the limitations of physical examination [3].

The current indications, modalities, and approaches for neurologic monitoring in critically ill children will be discussed in this review. The topics of traumatic brain injury (TBI), cardiac arrest, stroke, central nervous system (CNS) infection, and critical illness that increases the likelihood of brain dysfunction will be the primary focus of this discussion. Multimodal monitoring, computed physiologic indices, and noninvasive methods, among others, will be highlighted in recent research [4].

In critical care, electroencephalography (EEG) is a key component of neuromonitoring. Up to one third of EEG-monitored children have seizures following moderate or severe TBI, and forty percent only have nonmotor, electrographic seizures. Posttraumatic symptomatic epilepsy, which can result in long-term cognitive dysfunction, affects one in five critically ill children with TBI. Neurovascular

coupling, the imbalance between blood flow and neuronal metabolic demands that causes seizures, is linked to a metabolic crisis in brain tissue and may increase the risk of secondary brain injury. Epilepsy prevention for seven days with phenytoin or levetiracetam is emphasized in the current TBI guidelines. The suppression of bursts during barbiturate therapy for refractory intracranial hypertension can be monitored using EEG. In a small number of pediatric patients with severe TBI who required additional invasive neuromonitoring, intracranial EEG has also been used. This method has the potential to improve the detection of secondary neurologic insults if it is further validated [5,6].

The term "quantitative EEG" (QEEG) refers to a variety of electrographic features derived computationally from EEG. These features include the calculation of peak envelopes, amplitude-integrated EEG, quantification of waveform frequencies using Fourier and wavelet analysis, and determination of suppression ratios. QEEG has been shown to be useful for prognosis in adult TBI. Vespa and co. found that a poor outcome or death was predicted by a lower alpha variability [7].

EEG has been used in addition to clinical examination for monitoring and prognosis following cardiac arrest due to the limitations of clinical examination. After cardiac arrest, nearly half of children experience electrographic seizures, which are linked to worse outcomes. The use of EEG in prognostication is also supported by new evidence. Positive neurologic outcomes are associated with normal background EEG activity. There is a negative correlation between abnormal findings like burst suppression and the outcome. Children's outcomes after cardiac arrest have been predicted by models with multiple EEG features. The growing use of QEEG might make objective neuromonitoring and prediction of outcomes better. A model with QEEG features and an area under receiver-operator characteristic curve of 0.88 was highly predictive of outcome after cardiac arrest in a prospective observational study of 87 children. A recent case series demonstrates that asymmetric QEEG findings may occur prior to clinically apparent severe neurologic decompensation. Neonatal hypoxic-ischemic encephalopathy can be diagnosed with amplitude-integrated EEG, which displays peak-to-peak amplitude in a semilogarithmic manner. Amplitude-integrated electroencephalography (EEG) was recently used to detect seizures and predict the outcome of pediatric cardiac arrest. In a small prospective study of children with nontraumatic disturbance of consciousness, a model incorporating amplitude-integrated EEG was highly predictive of neurologic outcome. In circumstances where standard continuous EEG is impractical due to limited resources, this method may be especially useful [8,9].

One in five children who suffer an acute stroke experience seizures. As a result, children with stroke, seizure, or altered mental status typically undergo an EEG. QEEG might be more useful. Characteristic QEEG patterns were observed in injured and uninjured brain regions in a recent study involving 11 children who had either an ischemic or hemorrhagic anterior circulation stroke. The spectral power of those who had a stroke caused by hemorrhage varied with arterial blood pressure. These intriguing preliminary findings may lead to improved physiologic monitoring of the stroke penumbra if validated in larger studies.

Current guidelines recommend EEG monitoring for patients receiving ECMO support and those requiring pharmacologic neuromuscular blockade while at risk of seizures because seizures are linked to higher mortality rates. In two single-center retrospective studies, an EEG was used to monitor roughly half of pediatric ECMO patients. Between 16% and 22% of people experienced electrographic seizures, which were linked to death and intracranial hemorrhage. Patients who are critically ill and have encephalitis also have a higher risk of seizures and frequently require continuous EEG monitoring.

CONCLUSION

A multimodal approach should be used for intensive monitoring of many children with acute neurologic pathology. Children who are critically ill run the risk of developing neurologic sequelae. It is important to take into account the underlying pathophysiology, the capabilities of local monitoring, and how national guidelines are compared to new evidence. Improved outcomes and personalized care may result from monitoring methods based on CBF, oxygenation, autoregulation, and intracranial compliance principles. In order to improve methods for multimodal physiologic monitoring, efforts are being made to further validate these modalities. In contrast to advanced monitoring for other neurological conditions, which varies by institution, there are established guidelines for neuromonitoring in pediatric TBI. Innovative monitoring techniques may be incorporated into more widely accepted standardized approaches as they are further investigated in the pediatric population [10].

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