Brain Monitoring in Children

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KEYWORDS

- Near infrared spectroscopy • Electroencephalography • Bispectral Index
- Amplitude-integrated electroencephalography • Oxygen • Cerebral function
- Cardiopulmonary bypass

KEY POINTS

- Electroencephalography (EEG) monitors are potential surrogate markers of conscious level and may detect effect of anesthesia on the cerebral cortex.
- Near infrared spectroscopy (NIRS) estimates cerebral oxygenation, which is affected by the balance between oxygen supply and demand.
- There is only weak evidence to support routine use of EEG or NIRS monitors to improve patient outcome.

INTRODUCTION

An anesthetist tries to keep a patient both alive and asleep during surgery. Monitoring is important to ensure that these objectives are met. Current practice is to prioritize the monitoring to ensure that anesthesia interventions maintain vital functions, such as arterial oxygen saturation, end-tidal carbon dioxide concentration, heart rate, and blood pressure. From these measurements, adequate oxygen delivery to the brain and other vital organs can be inferred. The adequacy of anesthesia can be judged by a combination of clinical observations of immobility and autonomic quiescence and also by the estimation of the concentration of anesthesia drug in the brain. These strategies are achievable and are standard, yet they may not be enough in some circumstances, and their accuracy is not certain.

Measuring unconsciousness is an ideal. Efficacy of anesthesia depends to a large extent on the concentration of anesthesia in the brain. Yet, this is not a simple concept. First, there is uncertainty about the concentration in blood. The assumption about an insoluble vapor achieving a steady state concentration in blood and therefore the brain is not supported by data, although few data are available to strengthen or weaken our assumptions. Data in adults measuring the washin and washout of 1% isoflurane show that there are delays between expired breath and blood concentrations, and, more importantly, there are wide limits of agreement within a patient group, which makes

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the prediction of blood concentration, from expired breath analysis, weaker than expected.[1] Similar variation exists between target and measured blood concentrations of propofol.[2]

The effective dose is guided by minimal alveolar concentration (MAC). Because MAC is a median value, it should be expected that some patients are not adequately anesthetized, and that the dose needs to be increased. Conversely, some patients are excessively anesthetized, perhaps with dangerous cardiovascular depression, and the dose needs to be decreased. The measurement of MAC itself has many problems.[3] Efficacy of a chosen dose can, to a degree, be assumed from immobility, yet, movement itself may be largely related to lack of suppression of the spinal cord rather than the brain.[4] It may be assumed, from our understanding of MAC studies, that the dose required to cause unconsciousness is lower than that required for immobility, which is reassuring, but the use of muscle relaxants removes the usefulness of immobility.

The sum of these considerations is that anesthesiologists should not be 100% confident about the effects of a specified anesthesia dose on the brain. This dose is too much for some patients and too little for others. This review examines monitoring devices that may help to reduce this uncertainty in children. Moreover, it focuses on direct brain monitoring rather than discussion of monitors of vital cardiorespiratory or autonomic functions, which are important but are indirect monitors of brain function.

The usefulness of direct monitoring may be best shown in the scenario of uncertainty about the adequacy of oxygen delivery to the brain. For example, hypotension is a common phenomenon in anesthesia,[5] and yet there is uncertainty about the lower limit of blood pressure that ensures safe brain oxygenation. If hypotension is assumed to be caused by cardiovascular depression by an excessive dose of anesthesia, what is the dose that is compatible with both safe brain oxygenation and unconsciousness? This problem may be one of the main causes for accidental awareness under anesthesia. Awareness in children[6] is uncommon, but the ability to monitor the brain, which helps to detect and prevent awareness, is a long-held aspiration for the specialty.

Brain monitoring for anesthesia needs to be simple, robust, and reliable. Monitors that use noninvasive skin sensors, placed on the scalp, should have these qualities. Monitors of the following are considered in this article:

- Cerebral electrical activity
- Cortical oxygenation

Monitors of blood flow are also important. Monitoring cardiac output and cerebral blood flow is valuable but these topics not considered in this article because they are not direct monitors of brain function. Moreover, they are not sufficiently developed, as yet, to be practicable in small infants in a wide range of settings.

ELECTRICAL ACTIVITY

Electroencephalography

Before discussing processed electroencephalography (EEG), an understanding of the raw EEG is essential. The EEG is believed to represent a composite of the postsynaptic potentials of the cerebral cortex. The origin of this activity, whether it is from central or peripheral parts of the brain, remains unclear, but there is evidence that thalamic signals play a key role in the arousal of the cortex. The EEG is a complex random-looking waveform and has many constituent oscillations of varying amplitude and frequency.

Signals are detected from skin electrodes placed on the scalp. The signal amplitude is smaller than the electrocardiogram (ECG) (microvolts compared with millivolts), and