19 Neuromonitoring in the Pediatric Patient

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Introduction

It is a truism that children are not just little adults. When a child comes for a surgical procedure, there are often additional pressures compared to an adult. For the neuromonitoring team involved in the care of a child, there are concerns and challenges related to the case that are pediatric-specific. In this chapter, the unique features of the pediatric patient and some surgical procedures that are pediatric-specific (or more common in the pediatric population) are considered. Although pediatrics is an important part of medicine and surgery, there are few textbooks on the neurophysiology of this population [1, 2] and even fewer on surgical neurophysiology.

Differences

The pediatric patient comes in a variety of sizes; the newborn baby is very small, while the older teenager is adult-sized. In Fig. 19.1 the average size spread of a newborn to adult is illustrated. There are periods of rapid growth (infancy, puberty) interspersed with periods of slower growth. The interested reader is referred to any textbook on pediatrics for more detail on the growth patterns [3]. At a simple level, the small size of infants makes placement of needles more tricky, especially as extra small needles are not typically available. The most difficult needles to place are those for the bulbocavernous reflex (BCR), typically involving stimulation of the dorsal penile or clitoral nerve. In the infant (especially female), these organs can be very small. As the child ages and grows, placement of needles gets a little easier because of the increased size.

When working with an adult, it is often possible to work in parallel with anesthesia and nursing, but in the smaller patients, this is not typically possible. This can lead to the setup taking a longer time than usual. The reduced size of the very young patient also means that they lose heat more quickly and so additional care will be needed to maintain body temperature. Low body temperature is associated with many negative surgical outcomes, including blood loss and infection [4]. Care should be taken to ensure that the patient therefore is covered as much as possible during needle placement. Such care will give you many points with nursing and anesthesia staff and be good for the patient.

In addition to being smaller than adults, the other major difference between adults and pediatric patients that applies to neuromonitoring is the degree of myelination in the nervous system and hence the conduction velocity. Unmyelinated

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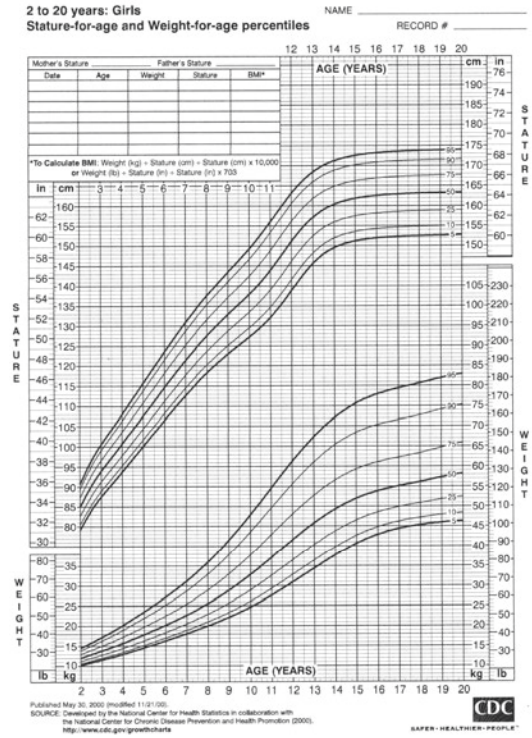
S. F. Davis, A. D. Kaye (eds.), *Principles of Neurophysiological Assessment, Mapping, and Monitoring*, https://doi.org/10.1007/978-3-030-22400-4_19



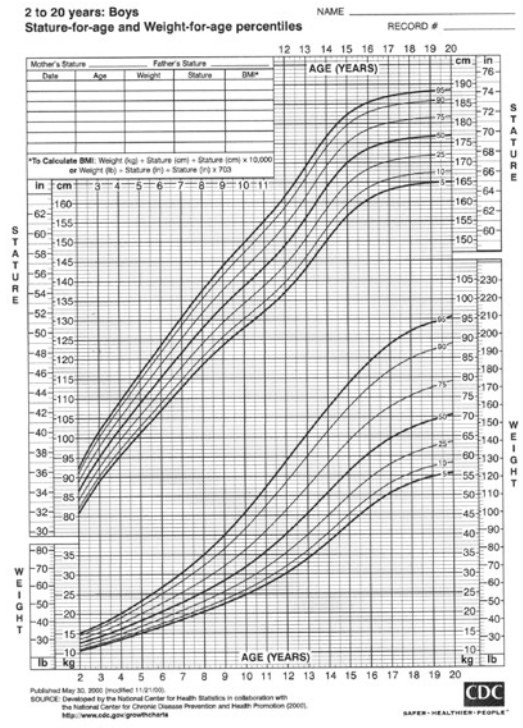


Fig. 19.1 The CDC growth charts for girls (left) and boys (right) from age 2 to 20 for both height and weight. Although these are typical curves, many pediatric surgical patients will fall off these curves. Graphs from Centers for Disease Control and Prevention (www.cdc.gov). Note that these are US curves; each country will have slightly different graphs

fibers conduct more slowly than heavily myelinated fibers; the myelination allows for saltatory conduction. The myelination is not fully complete until around the age of 20, and so the conduction velocity changes throughout the pediatric period. As the size increases and the conduction velocity increases, ultimately conduction delay for evoked potentials changes relatively little. The most comprehensive study on the maturation of the human nervous system comes from the work of Dr. Eyre in Newcastle, UK [5, 6]. The studies showed that there is only a small variation in the central conduction delay in both motor and somatosensory pathways once an infant reaches the age of 2 through to adulthood. There is a significant increase in the conduction velocity with age (Fig. 2 in [7]). These changes are related to axon diameter and myelination. Although there is substantial growth during puberty, the MEP latency is typically very close to mature (adult) values around the age of 5–9 years (Fig. 1 in [8]) [9]. Although these figures are from the recording of MEPs using transcranial magnetic stimulation, they hold for transcranial electrical stimulation and, in general, also for the SSEPs.

Anesthetic Issues

The pediatric anesthesiologist will be critical in obtaining good neuromonitoring [10] even more so than in adult patients. Providing a robust, safe anesthetic in infants is challenging, especially in the face of neurological issues that may be the surgical trigger. In particular, the blood volume in an infant is smaller, and so any blood loss is more significant. This can lead the anesthesia team to wanting to run the patient a little hypotensive, which can cause additional issues

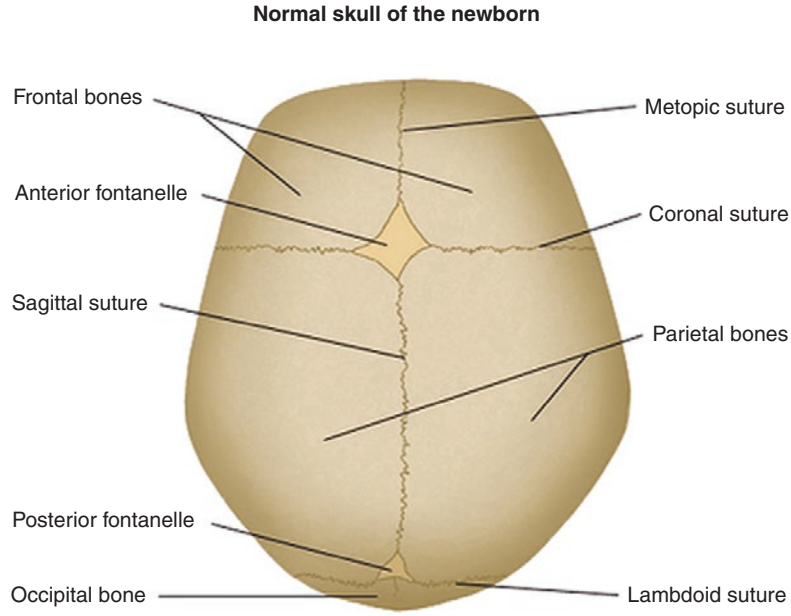


Fig. 19.2 The fontanelles at birth are open and close slowly over the first year of life. They can be palpated to determine their size and location in an individual child to ensure that electrodes are not placed directly over the fontanelle. Even with an open fontanelle, a corkscrew electrode will not reach deeper than the bone

with neuromonitoring. The anesthesia team may also be more reluctant to run a TIVA-type anesthetic. Propofol is a lipid-based anesthetic, and the fat distribution in infants is different than that in older children and adults, making the depth of anesthesia more difficult to predict.

A further consideration that is often at the forefront of the neuromonitorist's mind when dealing with infants are the fontanelles, which are open until about 9–12 months of age (Fig. 19.2). These are gaps in the bones of the skull (which allow for movement of the bones during vaginal birth). When performing MEPs, the voltages used are often very high (<300 V). These voltages are used because the bone is highly resistant and most of the voltage is shunted extracranially. When the skull is not intact, there is a much lower resistance pathway to the cortex. However, it should be remembered that direct cortical stimulation can be used, although the currents are much lower than transcranial stimulation. My personal approach is to firstly ensure that the stimulation electrodes are not placed over the sutures and then the stimulation voltage is slowly increased until MEPs are seen. When placing electrodes for SSEPs care is also taken to avoid the open sutures.

Surgical Procedures

Although children can have some of the same conditions that require surgery as adults, they also have some unique conditions. Myelomeningocele, scoliosis, and posterior fossa tumors are probably the three most pertinent for neuromonitoring.

Myelomeningocele

More commonly known as spina bifida, myelomeningocele is usually detected before birth and so the surgery is typically scheduled [11, 12]. When the neural tube is open and uncovered, closure of the defect is an urgent procedure. If the tube is partially covered, then the procedure may be delayed a little. The goal of the surgery is to close the neural tube and untether the spinal cord and nerve roots if needed. Root stimulation may be needed to identify roots and assist in placing them correctly in the canal [11, 13]. Motor evoked potentials can be used to determine which spinal levels are under (or will be under) voluntary control. Because these patients are likely to require many subsequent surgeries (neurosurgical,

orthopedic, etc.) [14] and may need to be catheterized long-term, it is advisable to treat them as latex sensitive, and so avoid using latex-based electrode fixation.

Spine Deformity

Much of the history of neuromonitoring is tied up with the monitoring of pediatric spine deformity surgery [15–17]. Many of the same considerations in adult spine surgery apply in pediatric surgery. Typically, however there is no use of interbody fusion devices, and often the fusion and instrumentation extend over a longer portion of the spine than is seen in adults. In idiopathic scoliosis, the patients are typically healthy, and predominantly female [18]. I am always a little more cautious when approaching a male with idiopathic scoliosis that is severe enough to warrant surgery. In addition to the idiopathic form, there are many non-idiopathic forms of scoliosis or other spine deformity, neuromuscular scoliosis, and infantile scoliosis presenting the most challenges in terms of monitoring. The neuromuscular form is often a gentler curve than other forms, but it arises because of a lack of voluntary motor control over the axial muscles, and so challenges in long-tract evoked potentials are to be expected. The infantile form may be treated by serial casting or bracing or non-fusion spine surgery using a growing construct. It is debatable whether monitoring is needed when these devices are lengthened [19]; however, it is our practice to monitor these cases, although with less channels than a typical fusion procedure.

Posterior Fossa Tumors

Tumors of the posterior fossa are by no means unique to children; however they do have different tumors than adults in that space. Intramedullary brainstem tumors are particularly aggressive in the pediatric population and often present to the neurosurgeon relatively late after being investigated for other causes of nausea, vomiting etc. The principles are the same as with adults; the tumor is approached at the point at which it is closest to the pial surface. Brainstem mapping is used to identify a "safe" entry zone avoiding the nuclei in the brainstem. For this to be successful, there must be good EMG recording from all of the muscles innervated by the nuclei [20–22]. Around the smaller muscles (eye, mouth), it can be tricky to accurately place electrodes if needles are used, and so to truly isolate the muscles, a small wire electrode should be used. Although the focus is on brainstem and cranial nerve monitoring, there remains a role for monitoring the long tracts that pass through the brainstem using both somatosensory and motor evoked potentials [23].

Tips and Tricks

The MEP is the most difficult potential to record in all patients, and especially in the pediatric population, more so in the neonate. The lack of myelination in the corticospinal tract can add further difficulties to these potentials because the potentials may reach the anterior horn cells at different times reducing the likelihood of a MEP in the muscle being triggered. My approach is to try using both double trains and longer inter-pulse intervals in an attempt to get as many action potentials arriving at and depolarizing the anterior horn cells.

The ABR is a relatively easy potential to record in neonates, and the SSEP while a little harder is still easily recordable using similar parameters to that used in adults.

Review Questions

1. What are two anesthetic considerations when monitoring the pediatric patient?
2. If the monitorist is having difficulty obtaining MEP recordings in the pediatric patient, what might they try?
3. Why are MEPs harder to obtain in young children?
4. What precautions should be taken when placing scalp electrodes in the pediatric patient?

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