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Interpretation of Lumbar Puncture Opening Pressure Measurements in Children

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Abstract

Background—Understanding the reference range of cerebrospinal fluid opening pressure (CSFOP) in children is essential to the diagnosis of elevated intracranial pressure. Recent studies have highlighted several clinical elements that need to be considered when interpreting CSFOP measures.

Evidence Acquisition—This review and recommendations are based on peer-reviewed literature, primarily from the past decade, as well as the author's clinical and research experience.

Results—CSFOP measures ≤28 cm H_2O can be considered "normal" for most children. The patient's depth of sedation, body mass index, and sedation medication can sometimes result in small increases in CSFOP. Patient age and leg position (flexed vs extended) in the lateral decubitus position do not seem to significantly impact CSFOP measures.

Conclusions—The threshold of a normal CSFOP should not be interpreted in isolation, but instead, in concert with other clinical and examination findings to help the physician make a well-informed assessment of whether a child has elevated intracranial pressure.

CASE REPORT

A 12-year-old boy presents with 3 months of unremitting holocephalic headache in the setting of an unremarkable comprehensive neuro-ophthalmologic examination without papilledema. He takes no medication, and his body mass index is 90th percentile for age. He underwent a sedated lumbar puncture (LP) using midazolam and fentanyl. The cerebrospinal fluid opening pressure (CSFOP) was 28 cm H_2O and, on awakening, the child stated he had relief of headache. His headache returned the next day, so he was placed on topiramate for headache prophylaxis. One month later, he underwent a second LP with a CSFOP of 27 cm H_2O, resulting in 1 day of headache relief. Neuroophthalmologic examination and magnetic resonance imaging (MRI) remain normal without any objective findings suggestive of

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elevated intracranial pressure (ICP). Does he have idiopathic intracranial hypertension (IIH)?

The CSFOP is a relatively noninvasive surrogate measure of ICP and an essential component of the diagnostic LP. An accurate interpretation of this commonly performed procedure is essential for the diagnosis and management of IIH (1,2). The reference range for a normal CSFOP in children has been described in the literature and seminal textbooks for over a century, despite the lack of empiric evidence to support these recommendations (2). In the past decade, a number of studies have questioned the previously recommended reference ranges for a normal CSFOP in both adults and children (3–5). These studies and others have also examined the impact of clinical factors, such as patient age, body mass index (BMI), depth of sedation, sedation medication, and body position that have long been speculated to influence the CSFOP values (3,4,6–13). This review examines the current data on CSFOP in children and attempts to provide a framework on how to interpret CSFOP.

ESTABLISHMENT OF A PEDIATRIC REFERENCE RANGE

Numerous studies and textbooks have listed a wide range of values for a normal CSFOP in infants and children (2). Rangwala and Liu (2) were the first to describe how many authors had cross referenced or incorrectly attributed their data to other articles, along with the lack of scientific rigor in developing these norms. It is likely that the normative values from the adult literature were adapted to pediatrics. In 1983, Corbett and Mehta (8) suggested that some normal adults may demonstrate a CSFOP as high as 25 cm H_2O. However, the pediatric literature did not adapt this range and continued to endorse values of 20 cm H_2O and lower as being normal (2,8). A decade later, Ellis (5) performed LPs on pediatric oncology patients and concluded that the normal range of CSFOP was from 10 to 28 cm H_2O. Unfortunately, these findings frequently were not included in the pediatric literature, possibly due to the atypical method (i.e., counting the number of CSF drops for 21–39 seconds) of determining the CSFOP (5).

Ultimately, a large prospective study of adults confirmed the findings of Corbett and Mehta (8) and suggested that, at times, a normal CSFOP could be as high as 28 cm H_2O (3). This was soon followed by a large prospective study of children undergoing diagnostic LP and reported the mean CSFOP to be 19.7 cm H_2O and the 90th percentile being as high as 28 cm H_2O (4). Findings from a smaller cohort of pediatric patients also supported the fact that some children may have a CSFOP of up to 28 cm H_2O and can still be considered normal (14). Avery et al (15) provided additional support of their findings by reporting that 98% of children with optic nerve head edema believed to be secondary to elevated ICP demonstrated CSFOP measures $\geq$30 cm H_2O.

The recent studies mentioned above have helped guide clinicians and researchers in new directions. Specifically, the current CSFOP pressure data have been incorporated into the new diagnostic criteria for pediatric IIH (1). Second, the large adult (3) and pediatric (4) prospective studies listed above also highlighted the potential influence of clinical variables, such as BMI, age, depth of sedation, sedation medication, and body position that have long been speculated to influence the CSFOP values.

FACTORS AFFECTING CSFOP

Age

Many clinicians believe that CSFOP increases in early childhood until it reaches values similar to adults. Eight years of age has been discussed as a cutoff between pediatric and adult values (2). The study by Seiden et al (4), limited to children between 1 and 18 years old, did not find a statistically significant relationship between age and CSFOP. Even when age was dichotomized to above and below 10 years old, age and CSFOP were not related. When age was dichotomized above and below 7 years old, Ellis (5) also did not find a difference in mean CSFOP (19.1 vs 19.0, respectively). If differences in CSFOP exist between younger and older children, it is likely that interpatient variability, level of sedation, sedation medication, and other yet to be discovered factors have cluttered our ability to firmly establish this relationship. Until further research can prove a reliable influence of age on CSFOP, the same normative values can be applied to all children between 1 and 18 years old.

Body Mass Index

A statistically significant relationship between BMI and CSFOP previously has been reported in both pediatric and adult cohorts (3,4,14,16). Yet, a recently published large prospective study of adults with IIH found that CSFOP and BMI were not correlated (17). Similar to the results of Whiteley et al (3), the large pediatric study demonstrated that CSFOP increased by approximately 3 cm H_2O for every 10-unit increase in BMI after adjusting for the influence of other factors, such as sedation and age (4). Despite the statistical significance, these relatively small changes in CSFOP are unlikely to be clinically significant.

Sedation

Given the variability in sedation algorithms both within and between institutions, understanding the influence of specific medications on CSPOP has proven to be difficult. Ketamine has long been suggested to increase ICP and the CSFOP measures in children, (9,11,18), although some investigators have published data to the contrary (19,20). To date, only 1 prospective, randomized study has specifically evaluated the effect of ketamine on CSFOP and concluded that CSFOP was higher than in non-ketaminesedated patients (9). Seiden et al (4) did not find a statistically significant relationship between ketamine and CSFOP, although this study was not specifically designed to address this question and the analysis was limited by the relatively low number of patients receiving ketamine compared with other sedative agents.

Not only is class of sedation medication relevant, but also the patient's depth of the sedation is equally important. Pediatric patients who received moderate-to-deep sedation were found to have a CSFOP of nearly 3.5 cm H_2O higher than those not receiving any sedation medication (4). It is hypothesized that children deeply sedated likely experience a relative hypercapnia that contributes to elevated CSFOP (21). Lim and Lin (12) performed continuous monitoring of CSFOP while evaluating pediatric subjects' end-tidal pCO_2 and demonstrated a higher pCO_2 resulted in elevated CSFOP. Eidlitz-Markus et al (21) also

demonstrated a decrease in CSFOP as sedation was reduced and the child regained consciousness. Pediatric neurologists and neuro-ophthalmologists who perform LPs have suspected that deep sedation can result in even larger increases in CSFOP than have reported. To avoid sedating the child a second time, many LPs are performed immediately after completing a sedated MRI. Because the child has been sedated for approximately 1 hour, clinicians should be aware of the potential false elevation in CSFOP after prolonged sedation.

Currently, there is no agreed-on sedation protocol for performing a LP. When possible, using a low dose benzodiazepine for anxiolysis or no sedation altogether is preferred to avoid the known increase in CSFOP when undergoing moderate or deep sedation (4). For children who are awake or only receive anxiolysis, they should be monitored closely for agitation, which may increase intraabdominal pressure and falsely elevate the CSFOP (22). To reduce procedural discomfort, application of topical lidocaine-based cream 45 minutes before the LP can obviate the need for a subdermal injection of lidocaine.

Patient Position

Most pediatric LPs are performed in the lateral recombinant position with the legs flexed. Although it was commonly believed that the legs had to be extended to obtain an accurate CSFOP, many practitioners were hesitant to move the legs of a sedated or anxious child for fear of needle displacement or arousing the child. The difference of CSFOP between flexed and extended leg position does not result in a clinically meaningful change in CSFOP measures (6,7,23,24). Therefore, it is not necessary to move the awake or sedated child from the flexed to extended position.

CLINICAL SYMPTOMS

Headache relief after a diagnostic LP is frequently interpreted as proof that the child has elevated ICP. To date, no study has been performed to either support or refute this interpretation. The analgesic effect of commonly used sedation medications, such as narcotics, benzodiazepines, or barbiturates should be considered when interpreting headache relief after a LP. Furthermore, greater than one third of subjects reported by Michalczyk et al (9) never reported headache or other symptoms of elevated ICP despite having a CSFOP >27 cm H_2O. Other studies have also reported CSFOP >28 cm H_2O in subjects without signs or symptoms (including headache) of elevated ICP (3,4,13,14).

CASE FOLLOW-UP

Despite continued therapy, the child's headache persisted. Repeated neuro-ophthalmologic examinations and MRI/magentic resonance venography remained normal. A third LP demonstrated a CSFOP of 28 cm H_2O. Given the lack of therapeutic benefit from medications, an ICP monitor was placed and revealed consistently normal ICP readings (12 cm H_2O) over a 48-hour period. Because the child did not meet all of the necessary criteria for IIH (1), he was diagnosed as having chronic daily headache.

SUMMARY AND RECOMMENDATIONS FOR INTERPRETATION

The above case highlights both the inaccuracy of CSFOP measures by LP and inherent variability of ICP (25). It further reinforces that a single CSFOP value should not be considered in isolation and as the sole determinant of elevated ICP. When the CSFOP is below 28 cm H_2O, the clinician should be reassured that the subject likely does not have elevated ICP, especially in the absence of other objective findings. If clinical suspicion of elevated ICP persists, a follow-up examination is recommended. In children whose CSFOP is greater than 28 cm H_2O, it is not recommended that the value be classified as "abnormal," but instead the clinician should assess both the clinical findings and the circumstances of the LP (i.e., sedation, sedation medications, BMI, and patient agitation during the LP). Clinicians cannot be expected to calculate multivariable regression models in real time to interpret how 1 or more variables (i.e., sedation and BMI) have influenced their patient's CSFOP. So although a strict cutoff above or below 28 cm H_2O can be useful for research purposes, it certainly will not apply to all children. Instead, the threshold of 28 cm H_2O should be interpreted in concert with other clinical and examination results to help the clinician make a well-informed assessment of whether a child has elevated ICP.

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