Lumbar Puncture Pressures During Childhood in 262 Children with Craniosynostosis

Dong Ha Park[1] *and Soo Han Yoon*[2]

OBJECTIVE: **The aim of this study was to analyze age-dependent lumbar puncture pressures (LPPs) measured in 262 children with craniosynostosis to provide information that assists in determining surgery.**

METHODS: **From 1 July 2005 to 30 June 2014, 262 children with craniosynostosis diagnosed at the Department of Neurosurgery, Ajou University Hospital, underwent LPP measurement. These children were compared with respect to age, gender, birth weight, head circumference at the time of birth, gestational age, LPP, and developmental assessments.**

RESULTS: **Changes in LPP in children with craniosynostosis according to age were $y = -0.0007x^2 + 0.1327x + 21.678$ in all patients overall, $y = -0.0003x^2 + 0.1166x + 21.466$ in children with single-suture craniosynostosis, and $y = -0.002x^2 + 0.248x + 22.55$ in patients with multiple and syndromic craniosynostosis, indicating a steady and slow increase from birth until the age of 4 years. Also, 59.9% of the 262 children had LPP greater than 20 cm H_2O, but when the LPP cutoff level was adjusted for age, this proportion was 99.2%; the new criterion after the adjusted LPP cutoff level showed that for those with increased LPP, the proportion was 63.4%.**

CONCLUSIONS: **We suggest that LPP increases slowly with age in children with craniosynostosis, increased LPP rates in children with craniosynostosis were higher than previously expected, and the new cutoff level criterion that adjusts for age may be more helpful than a fixed cutoff level for all ages.**

INTRODUCTION

The cranial volume changes in children with craniosynostosis have been suggested to be lowest immediately after birth or within 6 months of birth compared with normal children, and therefore intracranial pressure (ICP) has been inferred to be highest during this same period.[1-4] It has therefore been proposed that the objectives for surgery in children with craniosynostosis are treatment of or prevention of complications that arise from increased ICP, and the cosmetic correction of the cranial deformity that ensues from craniosynostosis.[5,6] Although the criterion for increased ICP is important in the decision for surgery to prevent or treat increased ICP, infants differ from adults in that the cutoff level for this increased ICP is as yet equivocal.[7-10] The most commonly used standard for increased ICP cutoff level is greater than 20 cm H_2O (15 mm Hg) irrespective of the age of the patient.[7-10,12-18] However, Fok et al.[11] proposed cutoff levels from 3 cm H_2O to 20 cm H_2O according to age. In contrast, a recent series by Avery et al.[19,20] suggested that the LPP cutoff level should be a uniform 28 cm H_2O in children older than 1 year.

We classified 262 children with craniosynostosis whose LPP levels were measured by lumbar puncture (LP), with respect to ICP cutoff levels according to 3 criteria of increased ICP: the first criterion was more than 20 cm H_2O irrespective of age, the second proposed by Fok et al.[11] adjusts for age, and the third consisted of a 2-stage system of age-dependent increasing LPP cutoff level from 10 cm H_2O during the first year and Avery et al.'s constant LPP cutoff level after 1 year of age.[19,20] This study provides a better understanding of increased ICP in children with craniosynostosis.

METHODS

Selection of Patients

From 1 July 2005 to 30 June 2014, 262 children with craniosynostosis younger than 15 years diagnosed with craniosynostosis at the Department of Neurosurgery, Ajou University Hospital, underwent LPP measurements. This retrospective analysis was approved by the Ajou University Hospital institutional review board (MED-MDB-13-160, https://eirb2.ajoumc.or.kr). The 262 children comprised 212 with single-suture craniosynostosis and 49 with multiple and syndromic craniosynostosis. The mean age was 18 ± 23 months, the mean gestational age at birth was 39 ± 2 weeks, and the mean birth weight was 3.1 ± 0.5 kg (Table 1). Children excluded from this study were those with a previous history of

Key words
- Craniosynostosis
- Intracranial pressure
- Lumbar puncture

Abbreviations and Acronyms
ICP: Intracranial pressure
LP: Lumbar puncture
LPP: Lumbar puncture pressure

From the Departments of [1]*Plastic and Reconstructive Surgery and* [2]*Neurosurgery, Ajou University School of Medicine, Suwon, Korea*

To whom correspondence should be addressed: Soo Han Yoon, M.D. [E-mail: ee802000@yahoo.co.kr]

Citation: World Neurosurg. (2016) 92:234-240.
http://dx.doi.org/10.1016/j.wneu.2016.05.004

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

Table 1. Demographic Data of 262 Children with Craniosynostosis Who Had Lumbar Puncture

Classification	Number of Patients (Male:Female)	Mean Age (months)	Mean Gestational Age (weeks)	Birth Weight (kg)
Simple synostosis	213 (122:91)	16 ± 21	38 ± 3	3.1 ± 0.6
Sagittal	98 (69:29)	22 ± 27	38 ± 3	3.1 ± 0.6
Unilateral coronal	59 (23:36)	12 ± 14	39 ± 2	3.2 ± 0.4
Bicoronal	13 (4:9)	7 ± 7	38 ± 3	2.9 ± 0.7
Lambdoid	28 (17:11)	11 ± 11	39 ± 2	3.3 ± 0.5
Metopic	13 (9:4)	8 ± 11	37 ± 4	2.7 ± 0.7
Multiple and syndromic synostosis	49 (25:24)	28 ± 29	39 ± 2	3.1 ± 0.4
Multiple	22 (10:12)	34 ± 29	39 ± 2	3.1 ± 0.4
Syndromic	27 (15:12)	20 ± 24	39 ± 2	3.1 ± 0.5
Total	262 (147:115)	18 ± 23	39 ± 2	3.1 ± 0.5

surgery for craniosynostosis, those with shunts, children with Chiari anomaly expected to have difficult communication between the intracranial compartment and intraspinal spaces, and patients with microcephaly that was less than −2 standard deviations. A possible limitation of this study is that some patients with severe syndromic craniosynostosis who should have had early surgery in the neonatal period were not included.

LPP Measurements and Classification

Under general anesthesia with controlled inhalation anesthetics, the CO_2 concentrations were maintained at 35–40 mm Hg, and with the blood pressure maintained at preoperative levels, the LPP was measured manometrically in the recumbent position for 5–10 minutes. The jugular vein compression test was performed at least twice during the LPP measurements. The measured LPP levels were classified according to the following 3 criteria for increased LPP cutoff level: the first was greater than 20 cm H_2O (15 mm Hg) irrespective of age; the second was the cutoff level of linear function according to age by Fok et al.[11] (i.e., 3 cm H_2O starting at birth to about 7 cm H_2O at 12 months of age, and then the adult cutoff level of 20 cm H_2O at 10 years of age expressed as $y = 0.142x + 3$); the third new LPP criterion was determined differently for children aged less than 1 year and those aged more than 1 year and consisted of a linearly age-dependent increasing LPP cutoff level from 10 cm H_2O up to 28 cm H_2O during the first year expressed as $y = 1.5x + 10$ and Avery's LPP standard[19] of 28 cm H_2O cutoff level after 1 year of age. The LPP changes according to age were expressed as a 2-degree function.

Statistical Analysis

Statistical analyses were performed using a *t* test and χ^2 test, and P values and 95% confidence intervals were calculated.

RESULTS

The overall mean LPP was 24 ± 8 cm H_2O; children with single-suture craniosynostosis showed a mean LPP of 23 ± 7 cm H_2O, and children with multiple and syndromic craniosynostosis showed a mean LPP of 25 ± 10 cm H_2O, showing no statistical difference. The children with single-suture craniosynostosis who were classified as having sagittal craniosynostosis had a mean LPP of 24 ± 8 cm H_2O, the unilateral coronal had a mean of 22 ± 6 cm H_2O, the bicoronal a mean of 21 ± 6 cm H_2O, the lambdoid a mean of 26 ± 8 cm H_2O, and the metopic a mean of 21 ± 7 cm H_2O. The mean ICP of patients with multiple craniosynostosis was 25 ± 10 cm H_2O and was 25 ± 9 cm H_2O for those with syndromic craniosynostosis.

Our results showed that LPP changes according to age were as follows: overall, $y = -0.0007x^2 + 0.1327x + 21.678$, $y = -0.0003x^2 + 0.1166x + 21.466$ in the patients with single-suture craniosynostosis and $y = -0.002x^2 + 0.248x + 22.55$ in the children with multiple and syndromic craniosynostosis, with a slow and gradual increase from birth until about 4 years of age (Figure 1). Among the children with single-suture craniosynostosis, those with sagittal and unilateral coronal craniosynostosis showed a tendency for LPP increase until 5 years of age, whereas the children with lambdoid, metopic, and bicoronal craniosynostosis showed increasing ICP until 1–2 years of age, which decreased thereafter (Figure 2). In all patients with multiple and syndromic craniosynostosis, LPP increased until 3–4 years after birth and decreased thereafter (Figure 3).

The overall increased LPP was 59.9% according to the criterion for increased ICP greater than 20 cm H_2O. Among the patients with single-suture craniosynostosis, those with lambdoid craniosynostosis showed the highest increase incidence (75.0%), whereas those with bicoronal craniosynostosis showed the lowest increase incidence (46.7%), but with no statistical significance. There were 59.9% with increased LPP among the children with multiple and syndromic craniosynostosis: 63.6% in those with

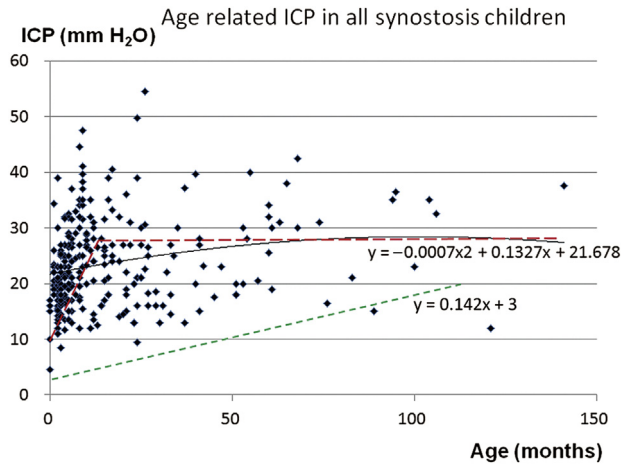

Figure 1. Lumbar puncture pressures and approximation curves in 262 children with all types of craniosynostosis according to age. A tendency for slowly increasing intracranial pressure (ICP) is observed for all children from birth until 5–6 years of age.