Comparing the Increased Intracranial Volume From Different Surgical Methods for Syndromic Craniosynostosis

Cheng Fang, MD,* Min Ji, MD,† ChenBin Dong, PhD,* Jun Li, MD,* and XiuYa Ye, MD*

Purpose: Fronto-orbital advancement (FOA) is the traditional surgical method used to increase intracranial volume, but posterior cranial vault distraction osteogenesis (PVDO) has been gaining popularity as an initial treatment option. This study aimed to compare the effects of FOA and PVDO on intracranial volume.

Patients and Methods: Sixteen patients with multiple-suture synostosis and severe intracranial volume restriction were treated with FOA or PVDO at Children’s Hospital of Fudan University between January 2016 and December 2019. Data on age at surgery, sex, preoperative intracranial volume, and postoperative intracranial volume were collected.

Results: Seven patients underwent FOA and 9 underwent PVDO. All patients underwent surgery for the first time, and the surgeries were performed by the same physician. There was no statistically significant difference in age at surgery or in the intracranial volumes before and after surgery between the 2 groups ($P > 0.05$). There was a statistically significant difference in the intracranial volume changes between the 2 groups before and after surgery ($P = 0.028$).

Conclusions: Posterior cranial vault distraction osteogenesis provided statistically greater intracranial volume expansion than FOA.

Key Words: craniosynostosis, fronto-orbital advancement, posterior distraction, intracranial volume

(J Craniofac Surg 2022;33: 2529–2533)
reconstruction of soft tissue, removed excess skin and soft tissue from the head and orbital regions, preserving the intact cranial soft tissue, and automatically calculating intracranial volumes.

**Statistical Analysis**

Patient characteristics and descriptive statistics were summarized and compared between the FOA and PVDO groups. Continuous data were compared using the t test, assuming equal variances. All calculated P values were 2-tailed and considered significant when P < 0.05. All statistical analyses in this study were performed using SPSS 25.0 software.

**RESULTS**

The patient characteristics in order of surgery are shown in Supplemental Table 1 (Supplemental Digital Content 1, http://links.lww.com/SCS/E165). All patients were diagnosed with a syndromic craniosynostosis, including 11 with Crouzon syndrome, 4 with Apert syndrome, and 1 with Saethre-Chotzen syndrome. Seven patients underwent FOA and 9 underwent PVDO. All patients underwent surgery for the first time, and the surgeries were performed by the same physician (corresponding author). All patients also underwent 3D CT examinations of the head a few days before surgery. Regardless of age at surgery, patients went to the outpatient clinic for follow-up visits for 8 to 10 months after surgery. After this period they were rechecked by 3D CT.

After obtaining the intracranial volumes by the methods listed above, we analyzed connections between the 2 groups’ data using SPSS 25.0, including the age of surgery, the intracranial volumes before and after surgery, and the difference in the intracranial volume before and after surgery. The results are shown in Supplemental Table 2 (Supplemental Digital Content 1, http://links.lww.com/SCS/E165). Although the average age of

![FIGURE 1](http://links.lww.com/SCS/E165)
surgery in the PVDO group was significantly earlier than in the FOA group, there was no other statistically significant difference between the 2 groups ($P > 0.05$). There was no statistically significant difference in intracranial volume before or after surgery between the 2 groups ($P > 0.05$). However, there was a statistically significant difference in the change in intracranial volume between the 2 groups before and after surgery ($P = 0.028$).

While obtaining the intracranial volume data, we reshaped the cranial cavity and compared the visual changes before and after surgery (Figs. 1–3). Figure 1 shows that FOA primarily changed the shape of the anterior cranial fossa, which was obviously enlarged, but the forehead line remained smooth. Figure 2 shows that PVDO primarily changed the shape of the posterior fossa, the diameter of which increased significantly. Figure 3 highlights visual changes to the brain parenchyma before and after surgery for the 2 groups.

DISCUSSION
In recent years, PVDO has gradually replaced FOA as the preferred initial surgical method for syndromic craniosynostosis. However, there have only been a few comparative studies on the changes in intracranial volumes between FOA and PVDO, and those have found that compared with the anterior cranial expansion by FOA, posterior cranial expansion achieves greater intracranial capacity, but there is potential bias. In this study, the bias was eliminated as much as possible. First, the age at surgery was basically the same, and there was no significant difference in age between the 2 groups, excluding the difference in the initial intracranial volumes. Second, both groups of patients were all at initial surgery, which excluded the influence of surgical overlap. Third, the postoperative follow-up time of the 2 groups was the same, excluding differences in postoperative developmental times. Therefore, the comparison of intracranial volume changes...
between the 2 groups in this study had a high degree of credibility. However, from Figures 2 and 3, it can be seen that the anterior fossa volume in the FOA group was significantly enlarged, while the posterior fossa was limited. Similarly, the anterior fossa volume in the PVDO group was enlarged, while the posterior fossa was limited. In other words, no matter whether FOA or PVDO was performed, there would be minimal changes to the unaffected cranium less, so some patients would have to undergo another surgery later.

There is still controversy about the choice of surgical age. Some studies have concluded that earlier surgery, even as early as 6 months of age, can relieve intracranial pressure early and reduce postoperative complications. However, the mean age at the time of PVDO was 16.2 ± 11.8 months, which was slightly earlier than the time of FOA. In this study, the average surgery age of FOA and PVDO was over 1-year-old, and the surgery age of FOA was greater than PVDO.

Some of the known complications after FOA and PVDO include that excessive FOA sometimes results in a strange facial appearance with a protruding forehead, especially in cases of syndromic craniosynostosis. The most common complications after PVDO are cerebrospinal fluid leakage or dural injury, followed by wound infections or device exposures, and device failure. Although cranium expansion surgery can enlarge the intracranial volume, it cannot reduce the probability of hydrocephalus after surgery. Postoperative complications in both groups in this study are being continuously followed-up.

A limitation of this study was its retrospective design. In addition, the sample size of this study was small. Another point of attention was the human factor when measuring intracranial volumes; for example, measurement errors or noncooperative children. Finally, both groups of children in this study were older in surgery.

CONCLUSIONS
In the retrospective study, PVDO provided statistically greater intracranial volume expansion than FOA. However, a prospective comparison of the risk/benefit ratio of posterior cranial vault distraction osteogenesis and FOA have to be launched to further define the optimal timing and sequencing of these 2 techniques.
REFERENCES

1. Mathijssen IMJ. Working Group Guideline Craniosynostosis. Updated guideline on treatment and management of craniosynostosis. J Craniofac Surg 2021;32:371–450
2. White N, Evans M, Dover MS, et al. Posterior calvarial vault expansion using distraction osteogenesis. Childs Nerv Syst 2009;25:231–236
3. Alford J, Derderian CA, Smartt JM Jr. Surgical treatment of nonsyndromic unicoronal craniosynostosis. J Craniofac Surg 2018;29:1199–1207
4. Swanson JW, Samra F, Bauder A, et al. An algorithm for managing syndromic craniosynostosis using posterior vault distraction osteogenesis. Plast Reconstr Surg 2016;137:829–841
5. Lo WB, Thant KZ, Kaderbhai J, et al. Posterior calvarial distraction for complex craniosynostosis and cerebellar tonsillar herniation. J Neurosurg Pediatr 2020;26:1–10
6. Kamil M, Oyoshi T, Komasaku S, et al. Fronto-orbital advancement and posterior cranial vault expansion using distraction osteogenesis in patients with multiple craniosynostosis. J Craniofac Surg 2021
7. Serlo WS, Ylikontiola LP, Lahdesluoma N, et al. Posterior cranial vault distraction osteogenesis in craniosynostosis: estimated increases in intracranial volume. J Childs Nerv Syst 2011;27:627–633
8. Choi M, Flores RL, Havlik RJ. Volumetric analysis of anterior versus posterior cranial vault expansion in patients with syndromic craniosynostosis. J Craniofac Surg 2012;23:455–458
9. Goldstein JA, Paliga JT, Wink JD, et al. A craniometric analysis of posterior cranial vault distraction osteogenesis. Plast Reconstr Surg 2013;131:1367–1375
10. Derderian CA, Wink JD, McGrath JL, et al. Volumetric changes in cranial vault expansion: comparison of fronto-orbital advancement and posterior cranial vault distraction osteogenesis. Plast Reconstr Surg 2015;135:1665–1672
11. Patel A, Yang JF, Hashim PW, et al. The impact of age at surgery on long-term neuropsychological outcomes in sagittal craniosynostosis. Plast Reconstr Surg 2014;134:608e–617e
12. Bennett KG, Vick AD, Ettinger RE, et al. Age at craniosynostosis surgery and its impact on ophthalmologic diagnoses: a single-center retrospective review. Plast Reconstr Surg 2019;144:696–701
13. Bruce WJ, Chang V, Joyce CJ, et al. Age at time of craniosynostosis repair predicts increased complication rate. Cleft Palate Craniofac J 2017;55:649–654
14. Greives MR, Ware BW, Tian AG, et al. Complications in posterior cranial vault distraction. Ann Plast Surg 2016;76:211–215
15. Thompson DN, Jones BM, Harkness W, et al. Consequences of cranial vault expansion surgery for craniosynostosis. Pediatr Neurosurg 1997;26:296–303