Numerous techniques have been developed to treat sagittal synostosis since Lane’s original description of the strip craniectomy in 1892. The endoscope-assisted craniectomy (EAC) technique for treatment of craniosynostosis, first pioneered by Jimenez and Barone and reported in the literature in 1998, has reported benefits over open calvarial vault reconstruction when performed in the first 6 months of life. The EAC technique has shown decreases in operative time, blood loss, transfusion requirements, cost, and hospital stays. Postoperatively, the infants wear custom-made cranial molding helmets to augment the reshaping of their calvaria.
The EAC method for treatment of sagittal synostosis has 2 variations. The approach proposed by Jimenez and Barone relies on an endoscope-assisted wide (4–6 cm) vertex craniectomy of the sagittal suture in addition to biparietal and bitemporal “barrel-stave” or wedge osteotomies.\textsuperscript{3,5,7} A second approach reported by Ridgway et al. relies on less bone removal through an endoscoope-assisted narrow (approximately 2 cm) strip vertex craniectomy.\textsuperscript{1,11} Both use postoperative cranial molding helmets and have shown effectiveness in treating sagittal synostosis. However, no study has directly compared the techniques. Here, we evaluated these 2 techniques for endoscope-assisted correction of sagittal synostosis—wide vertex suturectomy and barrel stave osteotomies (WVS+BSO) and narrow vertex suturectomy (NVS)—and compared variables associated with surgery and clinical outcomes.

Methods
Patient Population
This was an age-matched retrospective study with the data collected in a prospective manner. Fourteen patients with isolated sagittal synostosis underwent NVS during the period from January 2012 to July 2013. These patients were age matched to 14 patients with isolated sagittal synostosis who had undergone wide vertex suturectomy and barrel stave osteotomies (WVS+BSO) at our institution from October 2006 to September 2011. Preoperative and postoperative clinical data have been prospectively collected at our institution since 2003. All patients underwent postoperative molding helmet therapy and were treated by a multidisciplinary team consisting of both a neurosurgeon (M.D.S.) and plastic surgeon (either K.B.P. or A.S.W.). Data collected included patient age, sex, operating time, estimated blood loss (EBL), postoperative hemoglobin, number of transfusions, complications, and cephalic index. Three-dimensional photographs were used to assess head shape preoperatively and postoperatively. The cephalic index was calculated as the ratio of the biparietal diameter to the anteroposterior diameter as measured by direct caliper measurements. The overall institutional goal cranial index for surgical repair of sagittal synostosis is 80. The Washington University institutional review board approved this study.

Surgical Technique
Wide Vertex Suturectomy and Barrel Stave Osteotomies
WVS+BSO was performed as described by Jimenez et al.\textsuperscript{3,7} After induction of general endotracheal anaesthesia, the patient was placed in the modified “sphinx” position, frequently with the use of a DORO headrest (Pro Med Instruments). Two transverse incisions were made: a 2-cm incision posterior to the anterior fontanelle and a 2-cm incision anterior to the lambda. After subgaleal dissection of the dura and sagittal sinus from the overlying fused suture. With the aid of the endoscope, a 4- to 6-cm-wide vertex craniectomy was performed using Mayo scissors. Bilateral osteotomies are performed using scissors posterior to each coronal suture and anterior to each lambdoid suture, down to the squamosal suture inferiorly. The endoscope was used to visualize the cut bone edges to allow for coagulation using a suction/cautery device set at 50 W. After hemostasis, the skin was closed in layers using absorbable suture.

Narrow Vertex Suturectomy
The NVS was performed as described by Ridgway et al.\textsuperscript{11} The surgery was performed similarly to the WVS+BSO technique, except a 2-cm-wide vertex suturectomy and no bilateral barrel stave osteotomies were performed.

Statistical Analysis
The 14 patients in the NVS group were age matched to 14 patients in the WVS+BSO group. Descriptive statistics were calculated, and Student t-tests were used to compare prospectively obtained data from the WVS+BSO group with the NVS group in a series of univariate analyses (Microsoft Excel 2010). The significance value was predetermined at $p < 0.05$.

Results
Patient Population
Fourteen patients underwent NVS from January 2012 to July 2013. Fourteen patients who underwent WVS+BSO during the period from October 2006 to September 2011 were aged matched to the NVS group. The average age of the NVS group was 3.8 months (range 2.1–6.5 months) and consisted of 10 males and 4 females (Table 1). The average age of the WVS+BSO group was 3.9 months (range 2.1–6.6 months) and similarly consisted of 10 males and 4 females (Table 1).

Surgical Procedures
The 14 patients in the NVS group were compared with
TABLE 1. Demographic characteristics and surgical and clinical outcomes for NVS and WVS+BSO

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>WVS+BSO</th>
<th>NVS</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>14</td>
<td>14</td>
<td>0.96</td>
</tr>
<tr>
<td>Age in mos</td>
<td>3.9</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>2.1–6.6</td>
<td>2.1–6.5</td>
<td></td>
</tr>
<tr>
<td>Sex (F/M), no.</td>
<td>4/10</td>
<td>4/10</td>
<td></td>
</tr>
<tr>
<td>Operative time in mins</td>
<td>83.4</td>
<td>59</td>
<td>0.001</td>
</tr>
<tr>
<td>Range</td>
<td>63–132</td>
<td>37–90</td>
<td></td>
</tr>
<tr>
<td>EBL in ml</td>
<td>28</td>
<td>25</td>
<td>0.60</td>
</tr>
<tr>
<td>Range</td>
<td>10–60</td>
<td>15–40</td>
<td></td>
</tr>
<tr>
<td>Preop hemoglobin (g/dl)</td>
<td>10.1</td>
<td>9.8</td>
<td>0.59</td>
</tr>
<tr>
<td>Mean</td>
<td>9–12.1</td>
<td>9–11.6</td>
<td></td>
</tr>
<tr>
<td>Postop hemoglobin (g/dl)</td>
<td>8.0</td>
<td>8.6</td>
<td>0.24</td>
</tr>
<tr>
<td>Range</td>
<td>5.5–11.9</td>
<td>7.2–10.4</td>
<td></td>
</tr>
<tr>
<td>No. of transfusions</td>
<td>1 (7)</td>
<td>0</td>
<td>0.33</td>
</tr>
<tr>
<td>Preop cephalic index</td>
<td>68.2</td>
<td>69.9</td>
<td>0.27</td>
</tr>
<tr>
<td>Mean</td>
<td>63–75</td>
<td>62–78</td>
<td></td>
</tr>
<tr>
<td>Postop cephalic index</td>
<td>77.2</td>
<td>78.1</td>
<td>0.60</td>
</tr>
<tr>
<td>Mean</td>
<td>72–86</td>
<td>73–85</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

their age-matched cohorts in the WVS+BSO group in terms of operative time, EBL, postoperative hemoglobin level, number of transfusions, and complications (Table 1 and Fig. 1). The mean operative time for patients undergoing NVS was 59.0 minutes, significantly less than the 83.4-minute operative time for patients undergoing WVS+BSO (p < 0.05). The mean EBL for patients undergoing NVS was 25.4 ml, which was not statistically significantly different from the mean EBL for patients undergoing WVS+BSO (27.5 ml). The mean postoperative hemoglobin level was 8.6 g/dl (range 7.2–10.4 g/dl) for the NVS group, which was not statistically significantly different from 8.0 g/dl (range 5.5–11.9 g/dl) for the WVS+BSO group. No patient in the NVS group required a transfusion, and 1 patient (7%) in the WVS+BSO group required a postoperative transfusion due to a decreasing hemoglobin level below 8 g/dl, with the patient becoming symptomatic. There were no surgery-related complications in either group.

Surgical Outcomes

Each infant was evaluated and fit for a cranial molding helmet in the perioperative period and monitored until 1 year of age. The cephalic index was obtained preoperatively and then postoperatively at 1-month intervals until 1 year of age (Table 1 and Figs. 1 and 2). The mean preoperative cephalic index was 69.9 in the NVS group, which was not statistically significantly different from a cephalic index of 68.2 in the WVS+BSO group (Table 1). The average cephalic index at 1 year of age was 78.1 in the NVS group, which was not significantly different from an average cephalic index of 77.2 in the WVS+BSO group. Just as the postoperative cephalic index at 1 year of age was not different between the groups, there was no statistically significant difference in the postoperative monthly cephalic indices between the groups in the immediate months following surgery. The WVS+BSO group obtained the final cephalic index in a similar amount of time postoperatively as the NVS group (Fig. 2). Helmet therapy continued until 1 year of age for all patients in each cohort, and thus helmeting time was not significantly different between the groups. Three-dimensional CT representative examples of isolated sagittal synostosis before and after treatment with WVS+BSO and NVS are shown in Fig. 3.

Discussion

Sagittal synostosis has been treated using various surgical methods. Comparing operative approaches is important to determine the best treatment strategy for each patient. Here, we compared NVS and WVS+BSO to determine if there was any difference in operative and clinical outcomes. We found that the mean operative time for NVS was 29% less than the average operative time for WVS+BSO (p < 0.05). There was no difference in EBL, postoperative hemoglobin level, and complications between the 2 endoscope-assisted procedures. Both procedures achieved a similar clinical outcome upon completion of molding helmet therapy. The average cephalic index at postoperative follow-up at 1 year of age for each method was nearly the same. No difference in cephalic index each month postoperatively was noted between the WVS+BSO and NVS groups.

The difference in length of procedure between the 2 techniques was not unexpected since the NVS requires less tissue dissection and less bone removal than the WVS+BSO. With only a 2-cm-wide suturectomy, less subgaleal soft-tissue dissection is needed in the NVS compared with the 4- to 6-cm-wide suturectomy in the WVS+BSO. The WVS+BSO also utilizes multiple barrel-stave osteotomies. This requires more subgaleal soft-tissue dissection in addition to the added time for barrel-stave osteotomies.

Interestingly, the EBL and postoperative hemoglobin levels were not significantly different between the 2 methods. Although the WVS+BSO required more dissection and osteotomies, most bleeding occurred from the dura overlying the sagittal sinus and from the diploe of the bone after suturectomy. Therefore, the size of the suturectomy did not significantly affect blood loss. The majority of the blood loss for the procedure presumably ended once the dural bleeding was controlled and the bone edges were cauterized.

The final clinical outcomes were unchanged between the 2 techniques. The cephalic index for the NVS was similar to that for the WVS+BSO at 1 year of age. The WVS+BSO group reached the final cephalic index in a similar time frame as the NVS cohort. Substantially more
bone is removed for WVS+BSO than for NVS and therefore less redirected brain growth is needed postoperatively, but this did not seem to affect cephalic index outcomes. In cases in which the parents were compliant with follow-up appointments and conscientious about ensuring the child wear the helmet 23 hours a day, the outcomes between the 2 procedures appeared to be the same. In both groups, the families and orthotists were counseled regarding aggressive helmeting therapy, and this was closely supervised by our center during the follow-up period to ensure a good correction.

**Limitations**

This was a single-center study, and the numbers were small. Therefore, the results found here may differ from results found in comparable studies performed at other institutions. Although the data were collected prospectively, the analysis was conducted in a retrospective manner.

**Conclusions**

The NVS and WVS+BSO methods produced nearly identical clinical results, as the cephalic index at 1 year of age was similar between the 2 approaches. However, the NVS required fewer procedural steps and significantly less operative time than the WVS+BSO. The WVS+BSO group obtained the final cephalic index in a similar amount of time postoperatively as the NVS group. Complications, transfusion rates, and EBL were not different between the 2 techniques.
References

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Disclosures

Dr. Patel reports that he is a speaker for Hanger Orthotics.

Author Contributions

Conception and design: Nguyen, Patel, Woo. Acquisition of data: Nguyen, Patel, Woo. Analysis and interpretation of data: Dlouhy, Nguyen, Patel, Hoben, Skolnick, Woo, Smyth. Drafting the article: Dlouhy, Smyth. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Dlouhy. Statistical analysis: Dlouhy, Nguyen, Hoben, Naidoo.

Supplemental Information

Previous Presentations

Portions of this work were presented as an oral presentation at the 43rd Annual Meeting of the AANS/CNS Section on Pediatric Neurological Surgery, December 4, 2014, Amelia Island, Florida.

Correspondence

Brian J. Dlouhy, Department of Neurosurgery, University of Iowa Hospitals and Clinics, 200 Hawkins Dr., Iowa City, IA 52242. email: brian-dlouhy@uiowa.edu.