Endoscopically assisted versus open repair of sagittal craniosynostosis: the St. Louis Children’s Hospital experience

Clinical article

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Object. This study investigated the differences in effectiveness and morbidity between endoscopically assisted wide-vertex strip craniectomy with barrel-stave osteotomies and postoperative helmet therapy versus open calvarial vault reconstruction without helmet therapy for sagittal craniosynostosis.

Methods. Between 2003 and 2010, the authors prospectively observed 89 children less than 12 months old who were surgically treated for a diagnosis of isolated sagittal synostosis. The endoscopic procedure was offered starting in 2006. The data associated with length of stay, blood loss, transfusion rates, operating times, and cephalic indices were reviewed.

Results. There were 47 endoscopically treated patients with a mean age at surgery of 3.6 months and 42 patients with open-vault reconstruction whose mean age at surgery was 6.8 months. The mean follow-up time was 13 months for endoscopic versus 25 months for open procedures. The mean operating time for the endoscopic procedure was 88 minutes, versus 179 minutes for the open surgery. The mean blood loss was 29 ml for endoscopic versus 218 ml for open procedures. Three endoscopically treated cases (6.4%) underwent transfusion, whereas all patients with open procedures underwent transfusion, with a mean of 1.6 transfusions per patient. The mean length of stay was 1.2 days for endoscopic and 3.9 days for open procedures. Of endoscopically treated patients completing helmet therapy, the mean duration for helmet therapy was 8.7 months. The mean pre- and postoperative cephalic indices for endoscopic procedures were 68% and 76% at 13 months postoperatively, versus 68% and 77% at 25 months postoperatively for open surgery.

Conclusions. Endoscopically assisted strip craniectomy offers a safe and effective treatment for sagittal craniosynostosis that is comparable in outcome to calvarial vault reconstruction, with no increase in morbidity and a shorter length of stay. (DOI: 10.3171/2011.5.PEDS1128)

Key Words • endoscopy • sagittal craniosynostosis • strip craniectomy • calvarial vault reconstruction • molding helmet therapy • surgical technique

Abbreviation used in this paper: AP = anteroposterior.

This article contains some figures that are displayed in color online but in black and white in the print edition.
Children’s Hospital. We compare the clinical variables associated with overall morbidity and efficacy of endoscopic versus open correction in children less than 12 months old.

Methods

Prospective Data Collection and Retrospective Analysis

Preoperative and postoperative clinical data have been prospectively collected by the senior authors (A.A.K. and M.D.S.) since 2003. Preoperative caliper morphometric data are obtained in the initial consultation by the plastic surgeon. Each child also has a craniofacial team consisting of a plastic/craniofacial surgeon, pediatric neurosurgeon, orthodontist, otorhinolaryngologist, audiologist, ophthalmologist, genetic counselor, speech pathologist, social worker, and psychologist for follow-up. Postoperative caliper measurements and helmet compliance are obtained and documented by a pediatric nurse practitioner (S.N.), or in some cases, the local orthotist.

The endoscopically assisted surgery was performed as detailed by Jimenez et al.10,11,12 After induction of anesthesia and intubation by the anesthetist, the patient is placed in the modified “sphinx” position, as demonstrated in Fig. 1.23 Two incisions are made: one just posterior to the anterior fontanel and the other just anterior to the lambda. After subgaleal dissection, bur holes and transverse osteotomies are made through each endoscopic access incision. The anterior osteotomy is connected to the posterior aspect of the anterior fontanel with Mayo scissors, providing access for the endoscope into the epidural space posteriorly. After the epidural space is dissected from the overlying bone with the aid of the endoscope, a 4- to 5-cm–wide vertex craniectomy is performed using Mayo scissors. The endoscope is also used to assist for visualization in coagulating the exposed edges with a suction/Bovie cautery device set at 50 W (Fig. 1D). After hemostasis, the skin is closed in layers by using absorbable suture. The patient is subsequently extubated, brought to the recovery area, and then to the ICU for an overnight stay before discharge in almost all cases.

On postoperative Day 4–5, the child is fitted for his or her first in a series of 2–3 cranial molding helmets. The child wears the helmet 23 hours per day. It is only taken off to clean the helmet and check the incision sites several times per day. Patients living locally use a helmet manufactured by a local orthotic provider. Patients who live outside of the St. Louis metropolitan area are referred to local offices of a national orthotic provider (Hanger Orthotics) for molding helmet therapy. A nurse practitioner (S.N.) follows the patients for compliance every 1–3 months until termination of helmet therapy at approximately 1 year of age. All patients receive a 3D low-radiation-protocol head CT scan before discharge (Fig. 3).

Study Methods

After obtaining appropriate institutional review board approval, the charts of 89 consecutive nonsyndromic sagittal craniosynostosis cases in children less than 12 months old were identified between June 2003 and October 2010. (The data were collected prospectively from the inception of the program in 2003.) A total of 47 endoscopic and 42 open calvarial vault reconstruction cases were performed by 1 neurosurgeon (M.D.S.) and 3 plastic surgeons (A.A.K., 38 endoscopic and 26 open; A.S.W., 9 endoscopic and 15 open; and 1 former faculty member [see Acknowledgment, 1 open]). The clinical variables associated with age, sex, operating time, blood loss, number of transfusions, length of stay, complications, cephalic index, helmet therapy time, and last follow-up time were recorded. The cephalic index was calculated as the ratio of the biparietal diameter to the AP diameter as measured by calipers. A Student t-test was used to calculate significant differences in the continuous variables. A Yates corrected chi-square test was used to compare significant differences in the categorical variables like the patient’s sex and transfusions (Microsoft Excel 2007). The significance value was predetermined at p < 0.05.
Results

The demographic data and postoperative results of the patients are detailed in Table 1. The mean age at surgery was significantly different between the 2 groups, with the endoscopic group 3.6 months old (range 2–7 months) and the open reconstruction group 6.8 months old (range 4–12 months) at surgery, although the ranges overlap substantially. This was partially reflective of the mean age at presentation of 2.4 months in the endoscopic group versus 4.5 months in the open group (p < 0.001), and also the fact that time to surgery after presentation was 1.2 months for the endoscopic group and 2.4 months for the open group (p < 0.001). There was a predilection for males in both groups, with 74% of the infants in the open group and 68% of the endoscopically treated patients. The operating time was significantly shorter in the endoscopic group, at 88 minutes, versus 179 minutes for the open group. The average blood loss was 29 ml in the endoscopic group, or approximately 5% of the estimated blood volume for a 3-month-old infant, versus 218 ml in the open group, or approximately 25% of estimated blood volume for a 6-month-old child. All patients undergoing the open procedure received intraoperative blood transfusions, with a majority requiring additional blood postoperatively in the ICU, whereas only 3 (6.4%) of the endoscopically treated patients received transfusions. After 2 endoscopically treated patients received transfusions postoperatively due to fear of progression of asymptomatic anemia, a more rigid transfusion protocol was implemented for patients in the endoscopic group. In the new protocol, anemia with
a hematocrit of 18.0% or less was required, after which only 1 patient needed transfusion. Almost all endoscopically treated patients were discharged the morning after surgery, whereas the patients with open reconstruction stayed for a mean of 3.9 days. The morphometric cephalic index ratio improved from 68% to 76% in the endoscopic group at a mean of 13 months' follow-up, and from 68% to 77% in the open group at 25 months. There were 29 patients in the endoscopic group who completed postoperative molding helmet therapy, with a mean helmet time of 8.7 months, and 7 patients who were not compliant (helmet therapy is ongoing in the other 11 patients).

There were 2 complications in the open group. One patient had an air embolism from a peripheral intravenous line, causing the procedure to be stopped. The procedure was completed 1 week later with no further issues. The second patient had a small wound defect along the bicoronal incision a few months postoperatively, necessitating wound revision, and recovered without further complication. There was 1 endoscopically treated patient who had a persistent vertex defect at 5 years of age that was addressed with a small titanium mesh cranioplasty, with satisfactory results. This patient had undergone endoscopic repair at nearly 6 months of age. There were no infections, deaths, or other serious complications.

**Discussion**

This study presents the results of 47 children less than 12 months old who underwent endoscopic correction of nonsyndromic sagittal synostosis, and who had comparable outcomes to those in the 42 children with open calvarial vault reconstructions. Specifically, the endoscopically treated cases had substantially lower operating times, blood losses, transfusion rates, and hospital stay lengths than the open group, with comparable improvement in cephalic index postoperatively. There was a good mean outcome of cephalic index (> 75% in both groups). The primary demographic difference between the 2 groups was the age of the patient at surgery, which reflected the 2-month delay in presentation for patients with open reconstruction versus endoscopically treated patients, but also our tendency to delay surgery by an average of 1 additional month for open reconstruction cases to prevent perioperative morbidity. In our experience, the endoscopic technique is difficult to do after 6 months due to bone thickness. In addition, strip craniectomies are less efficacious in children older than 3 months. Conversely, the open technique exposes the very young to more blood loss. At our center, we transfuse all patients intraoperatively to avoid anemia-associated morbidities, and a similar practice has been reported in other series, without transfusion-related morbidity at an 81%–100% overall rate. Even when investigating alternative therapies, some series still report a high rate of transfusion, but Fearon and colleagues have reported that their transfusion rate is down to 19% from the original 57% they reported; they are using preoperative erythropoietin, and we are looking into this method as well. All families are offered preoperative donor-directed blood donation from family members; the blood is then made available for surgery, and many take advantage of this. Finally, we are in the process of designing a randomized, prospective study to assess the safety and efficacy of tranexamic acid added to the standard intraoperative transfusion regimen for our craniosynostosis cases. Overall, these comparable results between the 2 techniques, and the evidence that earlier correction of synostosis yields better outcomes emphasize the importance of early referral to a comprehensive craniofacial center.

The endoscopically treated patients also underwent the additional step of postoperative molding helmet therapy until they were 12 months old, but the optimal length of such therapy is debated. Interestingly, all 7 of the 36 endoscopic patients who did not comply with molding therapy had a good outcome, with a mean cephalic index of 79.6% at a mean follow-up time of 7.9 months postoperatively, although this follow-up time is limited. Noncompliance was determined by the lack of follow-up with both the orthotist for helmet adjustments and the nurse practitioner for head measurements. In a previous study with longer follow-up time, investigators concluded that strip craniectomy alone is not comparable to open reconstruction, so some degree of postoperative molding helmet therapy is potentially needed, but a prospective analysis would be needed to address this question. There are no substantial risks to molding helmet therapy, and we had no issues with alopecia as previously described. Nevertheless, the custom fitting of 2–3 helmets does entail an additional cost, between $3000 and $4500 without insurance coverage, raising a cost consideration, although the overall amount of savings for the endoscopic technique is still 61% compared with open reconstruction. Most of our patients had insurance coverage for the helmets, although this sometimes required assertive correspondence from the surgeon to the insur-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Endoscopically Assisted</th>
<th>Open, Patients &lt;1 Yr</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>47</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>no. of males</td>
<td>32 (68%)</td>
<td>31 (74%)</td>
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<tr>
<td>mean values</td>
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<tr>
<td>length of stay (days)</td>
<td>1.2</td>
<td>3.9</td>
<td>&lt;0.01</td>
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<td>transfusions</td>
<td>0.06</td>
<td>1.60</td>
<td>&lt;0.01</td>
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<td>age (mos)</td>
<td>3.6</td>
<td>6.8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>blood loss (ml)</td>
<td>29.0</td>
<td>218.0</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>op time (min)</td>
<td>87.8</td>
<td>179.0</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>preop cephalic index</td>
<td>67.7%</td>
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<tr>
<td>postop cephalic index</td>
<td>75.9%</td>
<td>76.9%</td>
<td>0.346</td>
</tr>
<tr>
<td>follow-up time (mos)</td>
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<td>24.6</td>
<td>&lt;0.01</td>
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<tr>
<td>helmet time (mos)</td>
<td>8.7</td>
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</table>

* The endoscopically assisted technique was significantly different from the open technique, with regard to shorter length of stay, minimal blood loss, and shorter operating time, while retaining similar demographic characteristics and mean postoperative cephalic index. Abbreviation: NA = not applicable.
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ance company. In our study, the need for postoperative molding helmet therapy was assumed to exist, but further studies are needed to elucidate whether a shorter helmet therapy time can have a comparable long-term outcome.

Currently, subjective, qualitative methods are used to assess such long-term outcomes as patient satisfaction.2,2,24 Anecdotally, we have seen good patient satisfaction with the cosmetic results, but have noticed a small prelabraloid vertex “dip” or a small bulge in the bregmatic region in a few cases, both open reconstruction and endoscopically treated, as demonstrated in Fig. 4. These observations are difficult to quantify. Quantitative methods have not significantly improved since the historical usage of cephalic index for racial comparisons, and this method is significantly limited because it takes 2 distinctly contoured surfaces, the frontal and parietal boss, and compares them as a scalar ratio. The more interesting mathematical comparison is the redistribution of volume along the convexity as well as the smoothing of the vertex. A more quantitative method is possible in this era of computationally intensive volumetric comparisons, and preliminary results by our group are promising. Application of volume-based methods will allow for better answers in population comparisons between surgical techniques. The one drawback to such quantitative methods is the necessity for postoperative 3D CT studies to best assess remodeling of the bone and potential islands of poor fusion.

At our institution we use a low-radiation-dose CT protocol, and we minimize the total number of scans to one early and one delayed postoperatively. The bone anatomy and remodeling are apparent in Figs. 2–3. The necessity of this CT study for surgical planning has been discussed in the literature, with the trend toward minimizing radiation.10,34 Although the need to minimize ionizing radiation is important, this should be counterbalanced against the need to have a modality with which preoperative diagnosis can be secured and postoperative outcomes assessed. Alternatively, 3D stereophotogrammetric or laser surface scans are a possible alternative to CT studies for morphological analysis, but they do not document suture patency or osseous dysmorphological characteristics, and the presence of hair can be problematic. Finally, we do not routinely obtain these CT scans in the endoscopically treated cases at 1 year anymore, because we are convinced of the technique’s efficacy. Because we are mostly transitioning to offering this option for sagittal synostosis correction, as demonstrated in Fig. 5, we are moving away from obtaining delayed CT scans in our patients.

This study has several limitations. It was not randomized, but the endoscopic technique previously had little primary outcome data20,23 to justify a controlled trial to compare techniques. The study was not powered to detect a small change between cephalic indices in the 2 groups. To detect a 2% difference in cephalic index with a population SD of 5%, with a significance level set at 0.05 and a power of 90%, 66 patients would need to be enrolled in each arm. Due to the rarity of the disease, a multicenter trial could answer this question more rapidly. There could have been a systematic bias in transfusion and hospital stay threshold, but it is predicated on the knowledge of the difference between techniques: endoscopic cauterization of bleeding bone edges versus subgaleal drain placement for the open reconstruction cases, allowing for continued venous bleeding. In addition, there is a follow-up time discrepancy between the 2 groups because the endoscopic technique was introduced later, but we will continue to collect data on these children prospectively, and future studies will report the longer term data.

Conclusions

Overall, this study demonstrates equal efficacy of endoscopic versus open correction of sagittal synostosis in nonsyndromic children less than 12 months old. The endoscopic procedure is safe, with markedly decreased operating time, transfusion risk, and hospital stay. It is tolerated well, with an equivalent mean cephalic index as compared with open reconstruction. The duration of and necessity for postoperative molding helmet therapy require further investigation.

![Fig. 4. Photographs showing anecdotal postoperative shape irregularities in both endoscopically assisted and open sagittal synostosis correction. Left: Note the perifrontal bulge (arrow) near the bregma. Right: Note the shallow dip on the vertex (arrow) just anterior to the lambda.](image)

![Fig. 5. Bar graph showing outcomes for various methods of correction for nonsyndromic sagittal synostosis. The numbers of open reconstruction and endoscopically treated cases over the study period are displayed. Note the transition from open to endoscopic correction at our institution over time.](image)
Disclosure

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Author contributions to the study and manuscript preparation include the following. Conception and design: Shane, Smyth. Acquisition of data: Shah, Kane, Woo, Naidoo, Smyth. Analysis and interpretation of data: Shah, Kane, Petersen, Woo, Smyth. Drafting the article: Shah, Kane, Petersen, Woo, Smyth. Critically revising the article: all authors. Statistical analysis: Shane, Smyth. Administrative/technical/material support: Kane, Naidoo, Smyth. Study supervision: Shah, Kane, Woo, Naidoo, Smyth.

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References

20. Lane LC: Pioneer craniectomy for relief of mental imbecility due to premature sutural closure and microcephalus. JAMA 18:49–50, 1892

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