Endoscopic craniectomy for early surgical correction of sagittal craniosynostosis

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Object. The authors sought to minimize scalp incisions, blood loss, and operative time by using endoscopically assisted strip craniectomies and barrel-stave osteotomies to treat infants with sagittal suture synostosis.

Methods. Four patients, aged 2, 4, 9, and 12 weeks, who presented with scaphocephaly underwent endoscopic midline craniectomies through small midline scalp incisions. The mean operative time for the procedure was 1.68 hours (range 1.15–2.8 hours); the mean blood loss was 54.2 ml (range 12–150 ml). Three patients did not require blood transfusions and were discharged within 24 hours. Postoperatively, all patients were fitted with custom cranial molding helmets. Follow-up evaluation ranged between 8 and 15 months. All patients had successful correction of their scaphocephaly with no mortalities, morbidities, or complications.

Conclusions. The use of endoscopic techniques for early correction of sagittal synostosis is safe; decreases blood loss, operative time, and hospitalization costs; and provides excellent early surgical results.

KEY WORDS • endoscopy • craniectomy • craniosynostosis • sagittal suture • scaphocephaly

Premature closure of the sagittal suture, the most common type of craniosynostosis, has an estimated incidence of three to five per 10,000 live births. Affected children present with scaphocephaly and other associated compensatory deformational changes. When treated early (< 2–3 months), a simple suturectomy or resection of the synostotic suture provides successful correction. However, by 6 months of age, the patients present with significant deformational changes that require major craniofacial reconstructive procedures. Even when performed early, correction of scaphocephaly by means of a strip craniectomy requires a bicoronal incision with extensive scalp mobilization, which can be associated with significant blood loss for an infant. Our goal was to introduce the use of endoscopes to minimize scalp incisions, blood loss, and operative times in patients undergoing midline strip craniectomies. The techniques used to achieve these goals and the results are described.

Clinical Material and Methods

Patient Population

Four patients, three boys and one girl aged 2, 9, 12, and 4 weeks, respectively (mean 6.75 weeks), presented with clinical signs of sagittal suture synostosis and were selected to undergo endoscopic midline strip craniectomies. All patients presented with scaphocephaly, bifrontal and occipital bosselation, and a midline bony ridge between the anterior fontanelle and the lambda. The patients’ weights ranged from 3.1 to 7.8 kg (mean 5.3 kg) (Table 1). The patients’ estimated blood volumes ranged between 248 ml and 568 ml (mean 410 ml). Their preoperative hematocrit levels ranged between 32% and 37% (mean 34%). All patients had undergone a plain skull x-ray film series and computerized tomography scanning, which demonstrated a stenosed sagittal suture.

Surgical Technique

Following endotracheal induction of general anesthesia, the patients were placed in the modified prone position on a pediatric bean bag. Two large-bore intravenous catheters were inserted without the need for central venous or arterial lines. After standard preparation of the surgical area with povidone–iodine solution, the scalp was infiltrated with lidocaine (0.25%) and epinephrine (1:200,000) at the incision sites. A 2-cm incision was placed directly over the anterior fontanelle and a second 2-cm incision was placed over the lambda (Fig. 1). Low-level needle-tip electrocautery was used to expose the fontanelle and the cranial bone. Monopolar electrocautery was used to expose the bone of the posterior edge of the anterior fontanelle 2 to 5 mm from the bony edges. Blunt dissection (Penfield No. 1 dissector) was used to separate the dura from the bony edges of the fontanelle. A 7-mm pediatric burr hole was placed paramedian to the lambda and in front of the lambdoid suture. Subgaleal dissection was...
performed between the lambda and the anterior fontanelle by means of endoscopic assistance with rigid 0°-angle 2.7-mm (Cordis Corp., Miami, FL) and 4-mm (Codman & Shurtleff, Randolph, MA) endoscopes and flexible 30,000-fiber scopes (Fig. 2). Needle-tip electrocautery was used with the aid of direct endoscopic visualization to develop a subgaleal and supraperiosteal dissection between the anterior and posterior incisions. This dissection was extended lateral to the superior temporal line bilaterally. The use of electrocautery for the subgaleal dissection was critical in minimizing blood loss and maximizing endoscopic visualization.

Using a periosteal elevator or a Penfield No. 1 dissector, the dura was dissected free from the overlying lambda and the posterior sagittal suture across the midline. A 2-mm Kerrison rongeur was used to remove a thin strip of bone across the midline immediately anterior to the lambdoid sutures. Dural dissection was continued along the lambdoid sutures laterally for 3 to 4 cm. Following dural dissection off the anterior fontanelle, the endoscope was gently placed under the bone and progressive epidural dissection under direct visualization was performed using the tip of a No. 5 or 7 French suction unit (Fig. 3). The dura was not attached to the overlying stenosed sagittal suture and complete exposure of the undersurface of the suture could be safely and rapidly achieved. Irrigation could be used to improve visualization. As performed in the subgaleal exposure, epidural dissection may have been extended laterally with flexible endoscopes to the level of the squamosal sutures. Following complete subgaleal and epidural exposure, lateral paramedian osteotomies were made using bone-cutting scissors (Fig. 4). A midline strip measuring 3 to 4 cm wide and 6 to 9 cm long can be removed through the anterior incision (Fig. 5). Strips of thrombin-soaked Gelfoam were placed alongside the osteotomy sites to minimize oozing and bleeding. Using direct visualization, three wedges of bone were removed from either side (3 × 5 mm), followed by an osteotomy extending laterally to the squamosal suture (Fig. 6). The proximal ends of the lambdoid sutures were removed in a similar fashion. The surgical field was irrigated with antibiotic solution and the scalp was closed with No. 4-0 Vicryl and sterilized strips. Postoperatively, the patients were placed in custom-made helmets that minimize anteroposterior growth and maximize bitemporoparietal growth and expansion (Fig. 7).

**Cranial Remodeling Helmets**

The cranial remodeling helmets were fabricated over a corrected model of the child’s head. A mold of the head was made using an elastic plaster bandage and a positive model was created by filling this mold with dental impression plaster. The model was then modified by adding plaster to areas where growth was desired; however, the plaster was not removed from areas where growth was to be restricted because compression was not desired. Three layers of 1/8-in medium-density foam padding were then molded over the corrected model. Expanded polyethylene

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**Table 1**

<table>
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<th>Factors</th>
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<tr>
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* EBL = estimated blood loss; EBV = estimated blood volume; EBVL% = estimated percentage of blood volume lost.
or ethylene vinyl acetate was used to make these concentric linings, which could be removed one at a time as the child grew. A 3/16-in sheet of polypropylene was then vacuum formed over these layers of foam padding to form a rigid shell.

The helmet was fitted to each child, trimmed just above the eyebrows, and extended as low on the occiput as possible without restricting neck extension. The helmet was trimmed clear of the ears and the crown was left solid. Holes were drilled to assist ventilation. In cases in which the helmet could be donned as is, a light elastic chin strap was provided, but most head shapes required that the helmet be cut vertically, releasing from the ear toward the crown, so that the helmet could be opened slightly and fitted over the occipital prominence. Hook and loop straps were then used to keep the donning slits closed once the helmet was in place.

Results

Follow-up evaluation ranged from 8 to 15 months. All patients tolerated the procedure well with no complications. Surgical time ranged from 1.15 to 2.8 hours (mean 1.67 hours). Estimated blood loss ranged from 12 to 150 ml (mean 54.2 ml); the estimated blood volume loss ranged from 2.3 to 26.4% (mean 12.1%). The three younger patients did not require blood transfusions; the 3-month-old child required a 150-ml transfusion and was found to have a very prominent and thick suture (2.1 cm). There was no dural tear, neural injury, or damage to the superior sagittal sinus. The dura and the epidural and subgaleal spaces were adequately visualized in all cases. There were no postoperative infections. All patients tolerated the custom-made cranial molding helmets well. There were no allergic reactions or skin breakdown. All patients have achieved and maintained normocephaly at 5, 6, 7, and 12 months, respectively (Figs. 8 and 9). Cephalic index measurements, (glabel–opisthocranion distance/100) obtained in all patients have indicated that their preoperative scaphocephalic shape (low index) has been corrected and normalization has been maintained (Fig. 10). Cost analysis of the hospitalization revealed that the average charge for this procedure (including surgeon’s fee and molding helmet) was $14,275. The average charge for a standard strip craniectomy is $21,320 and a total calvarial reconstruction procedure for older patients is $36,571 (charges based on price in midwestern United States; Table 2).

Discussion

The first craniectomies for the treatment of craniosynostosis were reported by Lannelongue in 1890 and Lane in 1892, who described the direct removal of the stenosed sagittal suture. Many procedures have since been developed for the treatment of scaphocephaly due to sagittal suture synostosis. Bilateral strip craniectomy,5,13 wide-strip

<table>
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<td><strong>Comparative mean hospitalization charges and LOH for patients undergoing surgical correction of stenosed sagittal sutures</strong></td>
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<tr>
<td>Procedure</td>
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<td>endoscopic strip craniectomy</td>
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<td>total calvarial remodeling</td>
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* LOH = length of hospital stay in days.
cranietomy with bilateral wedge parietal craniectomy, sagittal craniectomy with biparietal morcellation, subtotal calvarectomy, total vertex craniectomy, midline craniectomy with occiput resection, pi procedure, as well as total cranial vault remodeling with large bone flap elevation and bone flap transpositions have been reported.

Regardless of the method used for correcting sagittal craniosynostosis, most authors have found that this type of sutural synostosis is the one least amenable to complete and adequate long-term correction. Overall, there appears to be a tendency for scaphocephalic shape to occur in a number of these patients. In an attempt to manipulate postoperative cranial growth further, we have instituted cranial orthotic therapy. The helmets are designed to manipulate cranial growth so that normocephaly will rapidly be attained. Within 1 or 2 weeks of helmet therapy, significant changes have been noted. Our current policy is to continue helmet therapy for 3 to 4 months postoperatively. So far normal cranial shapes have been attained and maintained in all of the patients and helmet therapy has been well tolerated without problems or complications. A current study is underway to analyze the results of endoscopic strip craniectomy with and without helmet-molding therapy.

In the 1940s it was recognized that patient age at the time of the operation affects the surgical outcome in those undergoing correction of scaphocephaly. The younger the patient at the time of operation (<2 months), the less extensive the procedure required and the better the outcome. Adequately sized midline strip craniectomies in infants produce excellent results. Difficulties arise because primary care providers usually follow these patients and do not refer them to neurosurgeons until the patients are older than 6 months. In older patients with marked deformational changes, a strip craniectomy does not provide satisfactory results.

Infants have very small blood volumes and low hematocrit levels. Even “minor” blood losses can necessitate intraoperative blood transfusions. Elevation of a bicoronal or large longitudinal midline scalp incision can cause significant blood loss in these patients. The introduction of endoscopes to assist in the resection of midline craniectomies has reduced blood loss and operative time. Only

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**Fig. 5.** Intraoperative photograph showing removal of the midline strip through the anterior incision. Wide strips can be removed through small incisions by bisecting the bone.

**Fig. 6.** Left: Endoscopic view of the lateral edge of the strip craniectomy showing the barrel-stave osteotomies. Right: Artist’s view of the figure shown at left. A retractor is seen in the right upper quadrant, elevating the scalp. The wedge-shaped osteotomies are seen in the lower half of the diagram along with the underlying dura.

**Fig. 7.** Postoperative photograph of a patient in a polypropylene molding helmet. Anteroposterior growth is partially restricted while allowing increased bitemporal and biparietal expansion to achieve rapid normocephaly.

**Fig. 8.** Left: Preoperative lateral view of a 4-week-old girl who was born with a prominent, palpable midline osseous ridge, marked bifrontal bosselation, occipital cupping, and significant scaphocephaly. Right: Lateral view of the same infant 7 months postoperatively.
two small (2 \pm 0.5 \text{ cm}) incisions were required to remove the stenosed suture and create barrel-stave osteotomies bilaterally. Because the procedures were minimally invasive, the patients were discharged on the 1st or 2nd postoperative day (Table 2). Cost analysis indicates that the procedure produced a savings of 33% when compared with standard strip craniectomy and 61% when compared with extensive calvarial remodeling. All of the patients have attained normocephaly. The procedure was accomplished safely and rapidly. Our preliminary results indicate that the use of endoscopes to assist in performing strip craniectomies in young children is safe and cost effective, provides excellent results, and should be considered by surgeons treating infants afflicted with this disorder.

Disclosure

The authors do not have any financial interest in the instruments or the methodology described in this article.

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