Cost comparison of surgical management of nonsagittal synostosis: traditional open versus endoscope-assisted techniques

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OBJECTIVE Management of craniosynostosis at an early age is important for mitigating the risk of abnormal cranial development, but treatment can result in significant expenses. Previous research has shown that endoscope-assisted craniectomy (EAC) is less costly than open cranial vault remodeling (CVR) for patients with sagittal synostosis. The aim of this study was to strengthen the existing body of healthcare cost research by elucidating the charges associated with open and endoscopic treatment for patients with nonsagittal synostosis.

METHODS The authors performed a retrospective analysis of data obtained in 41 patients who underwent open CVR and 38 who underwent EAC with postoperative helmet therapy for nonsagittal, single-suture craniosynostosis (metopic, coronal, and lambdoid) between 2008 and 2018. All patients were < 1 year of age at the time of surgery and had a minimum 1 year of follow-up. Inpatient charges, physician fees, helmet charges, and outpatient clinic visits in the 1st year were analyzed.

RESULTS The mean ages of the children treated with EAC and open CVR were 3.5 months and 8.7 months, respectively. Patients undergoing EAC with postoperative helmet therapy required more outpatient clinic visits in the 1st year than patients undergoing CVR (4 vs 2; $p < 0.001$). Overall, 13% of patients in the EAC group required 1 helmet, 30% required 2 helmets, 40% required 3 helmets, and 13% required 4 or more helmets; the mean total helmeting charges were \$10,072. The total charges of treatment, including inpatient charges, physician fees, outpatient clinic visit costs, and helmet charges, were significantly lower for the EAC group than they were for the open CVR group (\$50,840 vs \$95,588; $p < 0.001$).

CONCLUSIONS Despite the additional charges for postoperative helmet therapy and the more frequent outpatient visits, EAC is significantly less expensive than open CVR for patients with metopic, coronal, and lambdoid craniosynostosis. In conjunction with the existing literature on clinical outcomes and perioperative resource utilization, these data support EAC as a cost-minimizing treatment for eligible patients with nonsagittal synostosis.

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KEYWORDS craniosynostosis; cost; endoscopic; cranial vault remodeling; fronto-orbital advancement; craniofacial

MINIMALLY invasive techniques for the treatment of all forms of single-suture craniosynostosis have gained in popularity since the introduction by Jimenez and Barone of strip craniectomy for sagittal synostosis in 1998.¹⁷ Endoscope-assisted craniectomy (EAC) has since also been employed in the treatment of metopic,

coronal, and lambdoid suture synostoses. Epidemiological studies have shown changes in the relative incidence of these diagnoses from previously accepted figures.^{22,33} Sagittal suture synostosis remains the most common form, but the most recent data indicate a rise in metopic synostosis, now regarded as the second most common type

ABBREVIATIONS CPT = Current Procedural Terminology; CVR = cranial vault remodeling; EAC = endoscope-assisted craniectomy; FOA = fronto-orbital advancement; LOS = length of stay.

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of craniosynostosis, followed by unicoronal and unilateral lambdoid synostosis.^{3,37,38} Together, these three nonsagittal single-suture fusions account for approximately 40% of patients with nonsyndromic craniosynostosis.²²

Traditional open treatment for metopic and unicoronal synostosis is fronto-orbital advancement (FOA).²⁶ Lambdoid synostosis is classically treated by posterior cranial vault remodeling (CVR).⁹ These open techniques are commonly and often exclusively practiced in craniofacial centers around the world. Endoscopic techniques combined with postoperative molding helmet therapy have shown promising postoperative outcomes, with the benefits of reductions of the following: blood loss, transfusion requirement, operative time, and duration of hospitalization.^{1,6,10,13,14,18,21,31,39} The endoscopic approach is becoming an increasingly appealing alternative to traditional open reconstructions. Concurrently, there has been increasing interest in the discrepancy in the costs of these two significantly different surgical approaches to the same cranial malformation. Multiple studies have investigated this question for the treatment of sagittal synostosis,^{1,31,39} but the literature addressing financial factors for the major forms of nonsagittal synostosis is lacking.

The primary aim of this study was to compare the charges for the 1st year of treatment for EAC with helmet therapy versus traditional open CVR for single-suture metopic, coronal, and lambdoid synostoses. The secondary aim was to describe the trends in treatment charges over time. We included all measurable charges in the 1st year of treatment, including perioperative hospitalization, physician fees, outpatient follow-up, and helmet therapy for the endoscopic cohort.

Methods

Study Design

This was a retrospective case-control study of patients treated at a single institution (St. Louis Children's Hospital, St. Louis, Missouri) over a 10-year period (2008–2018) by 3 plastic surgeons and 1 neurosurgeon for repair of single-suture metopic, coronal, and lambdoid synostoses. The study was approved by the Institutional Review Board of Washington University School of Medicine in St. Louis.

Patient Selection

All patients treated for nonsagittal craniosynostosis with either CVR or EAC between 2008 and 2018 were reviewed for eligibility. Patients treated at < 1 year of age for nonsyndromic single-suture nonsagittal synostosis (metopic, unicoronal, lambdoid), with a minimum of 1 year of clinical follow-up, were included in the study. Patients with syndromic or multisuture synostosis, inadequate follow-up, helmet therapy noncompliance, or lack of complete financial data were excluded from the study.

Treatment Protocol and Technique

The standard protocol at our institution for evaluation of children with craniosynostosis includes multidisciplinary preoperative evaluation by a craniofacial surgeon and a pediatric neurosurgeon, typically with 3D CT imaging to confirm the diagnosis of craniosynostosis, using

a low-dose radiation protocol. We offer both open and endoscope-assisted repairs to eligible patients presenting before 6 months of age (2–4 months preferred for coronal synostosis) and only open CVR to patients presenting for surgery after 6 months. In patients younger than 6 months of age, the decision to proceed with EAC versus open CVR is multifactorial and takes into account family preference and the ability to comply with postoperative helmet therapy. Our preferred approach for EAC in metopic synostosis has been previously published.²⁹ For coronal and lambdoid synostosis, we perform similar strip craniectomies along the fused suture line, 1–1.5 cm wide, ensuring lateral extension to the level of the squamosal suture for patients with coronal synostosis. Open CVR is performed using standard FOA techniques for metopic or unicoronal synostosis, and patients with lambdoid synostosis are treated with posterior CVR.^{25,30,34} For open CVR, we use a resorbable plating system (SonicWeld, KLS Martin). Patients treated with open CVR are admitted to the pediatric ICU for 1 night postoperatively, with transfer to a regular surgical floor on postoperative day 1. A closed-suction drain is placed subcutaneously and removed prior to discharge. Tapered doses of intravenous dexamethasone are given to minimize edema in all patients undergoing open CVR, beginning with an intraoperative dose.

Patients treated with EAC are admitted to a regular surgical floor postoperatively, and typically discharged home on postoperative day 1. Patients see the orthotist a few days prior to surgery for consultation and scanning for the helmet, and helmet therapy is typically initiated within 1–3 days postoperatively. Local orthotists fit patients with their first helmet in the hospital prior to discharge on postoperative day 1, and patients using more distant orthotic companies have an appointment within the first 3 postoperative days. Early helmet therapy initiation is facilitated by routine administration of 24 hours of intravenous dexamethasone to minimize edema. We recommend that the helmet be worn for 23 hours per day until the age of 12 months. All patients treated with EAC received postoperative helmet therapy from two major orthotic companies (Hanger Clinic and Orthotic & Prosthetic Lab, Inc.).

Our standard practice for postoperative follow-up after open CVR is one clinic visit at 3–6 weeks postoperatively and an additional visit at 1 year. Following EAC, patients are typically seen once at 3 weeks postoperatively, with frequency of subsequent visits determined by our familiarity with the treating cranial orthotist, as well as the patient's distance from our center. Patients meet with the orthotist every 2–3 weeks until the age of 6 months, then monthly until completion of helmet therapy. Multiple helmets may be required, and each new helmet incurs a charge, but there is no additional cost associated with orthotist visits for helmet adjustments. Most patients use a local orthotist, and we have implemented a telemedicine system for patients residing long distances from our center to reduce travel burden. Orthotic measurements are sent to the surgeon, and the patient and family communicate with us via telemedicine to follow helmet tolerance and head shape progression. Patients treated by less experienced orthotists are seen more frequently in person in our clinic for close monitoring of orthotic therapy.

TABLE 1. Summary of patient characteristics and treatment charges

Characteristic	Open Surgery	Endoscopic Surgery	Total	p Value
No. of patients	41	38	79	
Mean age at op in mos*	8.7 ± 1.9	3.5 ± 1.6	NA	<0.001
Synostosis type, no. (%)				
Metopic	20 (48.8%)	19 (50.0%)	39 (49.4%)	
Unicoronal	19 (46.3%)	12 (31.6%)	31 (39.2%)	
Lambdoid	2 (4.9%)	7 (18.4%)	9 (11.4%)	
Total	41	38	79	
No. of clinic visits in 1st year				
Mean*	2.0 ± 1.4	4.0 ± 2.2	NA	<0.001
Median	2.0	3.5	NA	
Periop charges*				
Hospital fees	\$66,652 ± \$16,206	\$23,695 ± \$6,732	NA	<0.001
Surgeon fees	\$25,054 ± \$9,577	\$14,489 ± \$2,041	NA	<0.001
Anesthesia fees	\$3,482 ± \$449	\$1,784 ± \$168	NA	<0.001
Mean helmet charges*	NA	\$10,072 ± \$4,059	NA	
Total charges†			NA	
Mean*	\$95,588 ± \$20,866	\$50,840 ± \$8,733	NA	<0.001

NA = not applicable.

* Values are expressed as the mean ± SD.

† Sum of perioperative charges (hospital, surgeon, and anesthesia fees), cost of outpatient clinic visits (estimated at \$200 per visit), and charges for helmet therapy (for the endoscopic group only).

Data Collection

Patient characteristics including diagnosis, age at surgery, length of stay (LOS), and insurance status were noted. Hospital financial records were reviewed for inpatient charges associated with the perioperative hospitalization, accounting for inpatient bed utilization, medical equipment, laboratory services, medications, and operating room supplies. Surgeon fees and associated Current Procedural Terminology (CPT) codes were collected, and anesthesia fees were noted. Outpatient records were reviewed for the number of postoperative clinic visits in the 1st year, with cost per visit estimated at \$200 to account for travel expenses and parental missed time from work.³⁹ For patients treated with EAC, data were collected from orthotic companies for number of helmets required per patient and charge per helmet. CPT coding data were collected for each patient.²

Statistical Analysis

The means, standard deviations, and interquartile ranges were calculated for age at cranial repair, inpatient charges, physician fees, outpatient clinic visits, and helmet therapy charges, as well as cumulatively for total charges in the 1st year of treatment. All charges were adjusted for inflation to reflect 2018 dollars (<https://www.minneapolisfed.org/community/financial-and-economic-education/cpi-calculator-information/consumer-price-index-and-inflation-rates-1913>). Distributions were found to be nonnormal; Mann-Whitney U-tests were performed to compare distributions of the two-subject groups on the aforementioned parameters. Bivariate correlations of age at surgery, LOS, inflation-adjusted total treatment charges,

helmet charges, and number of helmets with date of repair were analyzed with Spearman's rho. Fisher's exact test was used to compare proportions. To compare the distributions of diagnoses between the subject groups, a script (G. Cardillo, MyFisher; <https://www.mathworks.com/matlabcentral/fileexchange/26883-myfisher>) was run in Matlab R2017 (MathWorks), and the mid-p correction value was reported. All other analyses were executed with SPSS version 23 (IBM Corp.).

Results

We identified 79 patients who met our inclusion criteria—41 treated by CVR and 38 treated by EAC with postoperative helmet therapy. Patient characteristics and a summary of perioperative charges, cost of outpatient clinic visits, and helmeting charges are shown in Table 1. There was no statistically significant difference in the distribution of synostosis diagnoses between the two groups ($p = 0.112$). The mean age at surgery of patients in the EAC group was 3.5 months, whereas in the CVR group it was 8.7 months ($p < 0.001$). Neither the EAC ($r_s = -0.13$, $p = 0.439$) nor the open CVR ($r_s = 0.03$, $p = 0.872$) group had a significant correlation between age and date of surgery (Fig. 1).

The median LOS was 3 days for the open group (range 2–5 days) and 1 day for the endoscopic group (range 1–2 days). Only 1 patient in the endoscopic group (treated in 2008) stayed for 2 days postoperatively. Figure 2 shows the trends in LOS over time. There was a moderate negative correlation between LOS and date of surgery in the open group ($r_s = -0.54$, $p < 0.001$), with a trend toward decreasing LOS, and there were no stays longer than 3 days after 2014.

FIG. 1. Trends in age at surgery over time. Figure is available in color online only.

FIG. 2. Trends in LOS over time. Figure is available in color online only.

FIG. 3. Mean values for total charges of treatment in the 1st year are shown, as the sum of hospital, surgeon, and anesthesia fees, clinic visit costs, and helmet charges (for the endoscopic group). The mean charges for the 1st year of treatment for open CVR patients were significantly higher than those for EAC patients (\$95,588 vs \$50,840; $p < 0.001$). Figure is available in color online only.

In both the EAC and CVR cohorts, hospital fees made up the largest proportion of perioperative charges, followed by surgeon fees and anesthesia fees. Mean total treatment charges were significantly lower for EAC than they were for open CVR (\$50,840 $\pm$ \$8733 vs \$95,588 $\pm$ \$20,866; $p < 0.001$) (Fig. 3). Patients in the EAC cohort had significantly more clinic visits in the 1st year than the patients in the CVR group (4 vs 2 visits; $p < 0.001$) (Fig. 4). Figure 5 illustrates the trend toward increasing total charges for treatment over time. There was a strong positive correlation between charges for both open CVR ($r_s = 0.81$, $p < 0.001$) and EAC ($r_s = 0.61$, $p < 0.001$) and date of surgery.

The number of helmets required for each patient in the EAC group was variable: 13% of patients required 1 helmet, 30% required 2 helmets, 40% required 3 helmets, and 13% required 4 or more helmets, with mean total helmeting charges of \$10,072. The trend toward increasing

total charges for helmet therapy over time is shown in Fig. 6, with a moderate positive correlation between helmet charges and date of surgery ($r_s = 0.53$, $p < 0.001$). Figure 7 shows the trend toward increased number of helmets per patient over time, again with a moderate positive correlation between number of helmets and date of surgery ($r_s = 0.53$, $p < 0.001$).

One patient in the open CVR group and no patients in the EAC group underwent reoperation before age 5 years (19 [50%] of 38 EAC patients and 34 [83%] of 41 CVR patients had reached the age of 5 years at the time of analysis). This was a patient with metopic synostosis who had undergone FOA at 4 months of age and returned for cranioplasty with hydroxyapatite at 4.5 years of age to correct significant bitemporal narrowing and frontal prominence.

CPT coding was consistent between surgeons. All EAC procedures were filed under CPT code 21299-62 (unlisted craniofacial and maxillofacial procedure with 2-surgeon modifier). Open CVR for metopic and coronal synostosis was filed under CPT codes 21175 (reconstruction, bifrontal, superior-lateral orbital rims and lower forehead, advancement or alteration [e.g., plagiocephaly, trigonocephaly, brachycephaly], with or without grafts [included obtaining autografts]) and either 61557 (bifrontal bone flap) or 61559 (recontouring with multiple osteotomies and bone autografts [e.g., barrel-stave procedure] [includes obtaining grafts]). Open CVR for lambdoid synostosis was filed under CPT code 61559-62 (2-surgeon modifier).

The distribution of insurance types differed between the two groups: 41% of the open CVR cohort and 16% of the EAC cohort were insured by Medicaid, and 59% of the open CVR cohort and 84% of the EAC cohort were insured by private insurance ($p = 0.014$). In a subgroup analysis of patients residing locally in the greater St. Louis metropolitan area (https://www2.census.gov/geo/maps/metroarea/stcbsa_pg/Feb2013/cbsa2013_MO.pdf), this disparity was not significant. In this subgroup of 29 patients, there were 12 patients treated with open CVR and 17 patients treated with EAC: 17% (2/12) of the open CVR cohort and 12% (2/17) of the EAC cohort were insured by Medicaid, and 83% of the open CVR cohort and 88% of the EAC cohort were insured by private insurance ($p = 1.000$). There were no significant differences in total charges between privately and publicly insured patients for either procedure ($p = 0.812$ for open CVR, $p = 0.544$ for EAC).

Discussion

In the 2 decades since its introduction for the correction of sagittal synostosis,¹⁷ EAC with molding helmet therapy has gained traction as a viable treatment option for sagittal synostosis, but it is still not uniformly practiced across craniofacial centers for coronal, metopic, and lambdoid synostosis. The clinical advantages of endoscopic treatment of craniosynostosis over open CVR have been well documented and include decreased operative blood loss and transfusion requirements, as well as shorter operative times and LOS.^{1,6,10,13,14,18,21,31,39} An increasing body of literature from our institution and others has demonstrated promising outcomes in cranial morphology after EAC

FIG. 4. Box-and-whisker plots comparing number of clinic visits (left) and total charges (right) for treatment in the 1st year between open CVR and EAC groups. Upper and lower box borders indicate first and third quartiles. Whiskers indicate maximum and minimum values. Median values are marked with a horizontal line within each box. Figure is available in color online only.

FIG. 5. Trend in total charges for treatment in the 1st year. Figure is available in color online only.

FIG. 6. Trend in helmet charges over time (endoscopic cohort only). Figure is available in color online only.

with helmet therapy, equal or superior to those of open CVR.^{11,16,24,28,32,35,40,42}

With an increased focus on cost-effective healthcare delivery, previous studies have shown a significant decrease in financial burden with endoscopic treatment, most often demonstrated in patients with sagittal synostosis.^{1,8,19,23,31,39} Fewer data are available on the charges associated with surgical treatment of nonsagittal synostosis (metopic, coronal, and lambdoid), for which traditional open remodeling procedures are distinct from those for sagittal synostosis. Lambdoid synostosis is the least common of these 4 synostosis types, and there is a corresponding paucity of studies including these rare patients.

Two studies have reported cost comparisons between open and endoscopic treatments of nonsagittal synostosis but with significant limitations. Jivraj et al. recently reported a cost comparison for the treatment of unicoronal synostosis; because EAC is not practiced in the United Kingdom, the comparison was instead between data for open CVR (via FOA) performed at their center and data published by Jimenez and Barone for EAC performed in the United States, extrapolated to United Kingdom-equivalent charges.^{16,19} Though the study shows data consistent with our experience for decreased charges with endoscopic treatment, the data are difficult to apply to the United States healthcare billing model. Chan et al. previously published a comparison of costs for a pooled cohort of patients with coronal, metopic, and sagittal synostosis, including syndromic and multisuture cases,⁸ but the cost analysis was limited to the patients' hospital bills at dis-

charge combined with helmeting costs for the endoscopic group. Surgeon fees were not included, and monetary values were not adjusted for inflation in a data set spanning a 10-year time period.

Our study presents a complete single-center analysis of a large cohort of 79 patients from the past 10 years, elucidating in detail the charges associated with FOA or posterior CVR versus an endoscope-assisted strip craniectomy for metopic, unicoronal, and lambdoid synostosis. We have included a comprehensive set of charges associated with each procedure beyond the inpatient hospital fees, including surgeon and anesthesia fees, the cost of outpatient clinic visits, and helmeting charges in the endoscopic group. Inflation-adjusted financial data allow for better direct comparisons in this longitudinal cohort.

We have also demonstrated a more drastic difference in charges between EAC and open CVR for patients with nonsagittal synostosis than what has previously been documented for sagittal synostosis. Vogel et al. demonstrated in 2014 that EAC confers an approximately \$20,000 savings over the 1st year in the treatment of patients with sagittal synostosis compared with open CVR.³⁹ In the present study, EAC in the treatment of metopic, unicoronal, and lambdoid synostosis conferred an even greater mean savings of approximately \$45,000 when compared with conventional open treatment by FOA or posterior CVR, and the difference in charges between the two approaches has been increasing over time (Fig. 5). Contributing factors to this disparity may be the billing structure for CPT codes associated with FOA, which is a higher relative value unit

FIG. 7. Trend in number of helmets per patient over time (endoscopic cohort only). Figure is available in color online only.

procedure in craniofacial surgery,²⁷ and the need for more hardware (absorbable plates and screws) in FOA compared to CVR for sagittal synostosis treated in children younger than 1 year of age.

We have noted a trend toward decreasing LOS in our open CVR patients, with no patients staying longer than 3 days postoperatively since 2014. This coincided with our uniform implementation of postoperative intravenous dexamethasone treatment, which we have observed to markedly reduce edema formation. Despite these shorter hospital stays, the cumulative charges for open CVR have continued to rise over the years (Fig. 5).

While hospital charges make up the largest portion of the total charges in both open CVR and EAC, the significant charges for helmet therapy after EAC should be noted. Helmet therapy is an indispensable component of the endoscopic treatment strategy, and collaboration with an experienced orthotist is essential to achieving successful normalization of head shape. In the 10-year span of our data set, we have noted a trend toward a higher number of helmets per patient, translating to increasing overall charges for helmet therapy over time. The increase is due to our protocol of more aggressive head shape correction in the first few months of therapy, resulting in a shorter treatment period per helmet. In a changing insurance market that includes a trend toward high-deductible plans,^{4,15} this may be a consideration to address preoperatively with families, as some insurance plans may only provide partial coverage for helmet expenses.³⁹ The majority of our center's publicly insured patients are insured by Illinois or

Missouri Medicaid, and both cover 100% of all postoperative helmet fees.

We offer both endoscopic and open CVR options to every eligible family regardless of their ability to pay, and while our data show that a lower proportion of patients in the endoscopic cohort were publicly insured compared to those in the open CVR cohort, the disparity was insignificant on subgroup analysis of patients residing locally. This may reflect a referral bias, with privately insured patients more likely to travel a distance seeking a second opinion or the option of endoscopic treatment, which is not available at all centers. The trend toward an increasing total price of treatment, even after adjustment for inflation, reflects the nationwide increase in healthcare spending in recent years.^{4,7,15} Though routine treatment of congenital conditions is arguably not the worst offender in ballooning healthcare costs in the US, it is prudent for physicians to understand the financial profile of each major procedure they offer.

The limitations of our study include the retrospective, single-center study design and the analysis of financial variables over a long study period. We have attempted to mitigate the latter with mathematical adjustments for inflation. The single-center design confers an advantage relative to other published studies, as discussed above, but it may limit the generalizability of our data to other centers, where treatment and hospitalization protocols may differ significantly, especially with regard to postoperative ICU care. Bonfield et al.⁵ and Wolfswinkel et al.⁴¹ have reported promising safety outcomes without routine postoperative

ICU admission after open CVR, and elimination of ICU care may represent a significant reduction in overall hospital charges. The financial data available for our study do not specify the subgroups of charges comprising the overall hospital fee, and as such we cannot identify a single component responsible for the large difference in hospital fees between open and endoscopic treatments. Nevertheless, we recognize that ICU care is likely to be a significant contributor. We continue to routinely admit patients to the ICU for one night postoperatively after open CVR and would look forward to additional data on the safety of foregoing this practice prior to considering it as a cost-saving measure.

The use of resorbable plating systems may also not be universal across centers. Alternative methods of fixation used by some surgeons include wire, nonabsorbable suture, and absorbable suture, which may bring down the perioperative charges for open CVR.^{12,20,36}

We also recognize several limitations with respect to the calculation of overall costs. First, we used billed charges for hospital, anesthesia, and surgeon fees as a surrogate for true cost, which is the amount paid by the insurance company and/or patient. The actual amounts collected are not readily available, making charges the most practical substitute metric for these components of the overall cost. Second, travel expenses for orthotist visits were not included in this analysis because most of our patients used a local orthotist, and while the visits are free of charge and the financial burden of local travel is likely small relative to the total figures presented in this study, the time invested and potential wages lost for helmet adjustment visits are an additional component of the endoscopic treatment strategy that should be kept in mind when counseling patients. In addition, some states may not have comparable public insurance coverage of helmet therapy, which may significantly alter the costs to a family for endoscopic treatment at other centers. Third, while we accounted for estimated costs to the family for each outpatient clinic visit, the analysis did not include an estimate of opportunity costs for time spent away from home and work during the perioperative hospitalization. These costs would be most accurately measured with a prospective analysis.

We did not address complications in this cohort of patients. The cost of any complications requiring more frequent outpatient visits was captured in the analysis, but any complications requiring readmission were not included. Such complications are rare, and including the cost of a second admission or reoperation would not reflect the typical cost of treatment.

Finally, we observed a significant expected age difference between patients in the open CVR group and patients in the EAC group, which reflects our practice of offering EAC to a younger age group and the trend toward younger age at referral to our center in recent years. This may or may not directly affect the price of treatment, but reflects a sampling bias of the study.

Despite these limitations, our study illustrates a significant reduction in total charges for endoscopic treatment of metopic, coronal, and lambdoid synostosis relative to open CVR and adds valuable data to a literature dominated by studies of sagittal synostosis. Even with the significant

additional charges for helmet therapy and more frequent outpatient visits, endoscopic treatment charges total an average of \$45,000 less than those for open CVR for patients with nonsagittal synostosis.

Conclusions

In conjunction with the evolving data on successful clinical outcomes for normalization of head shape, our data support EAC as a cost-minimizing treatment for eligible patients with metopic, coronal, and lambdoid synostosis. Future investigations of long-term morphological and cognitive outcomes will be essential to the evolution of craniosynostosis treatment.

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Disclosures

Dr. Patel is a consultant for Stryker CMF and an educational speaker for Hanger Clinic. Dr. Naidoo is an educational speaker for Hanger Clinic.

Author Contributions

Conception and design: Patel, Zubovic, Skolnick, Smyth. Acquisition of data: Zubovic, Lapidus. Analysis and interpretation of data: Patel, Zubovic, Skolnick. Drafting the article: Zubovic. 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: Patel. Statistical analysis: Zubovic, Skolnick. Study supervision: Patel, Smyth.

Supplemental Information

Previous Presentations

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