

Sagittal Strip Craniectomy with Biparietal Morcellation in Children with Sagittal Craniosynostosis: 3D Outcome Analysis

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ABSTRACT

Sagittal craniosynostosis is a cranial anomaly treated with surgical intervention that can vary with timing and invasiveness. Although significant differences in protocol exist, current literature indicates that best outcomes result from suturectomy procedures performed before 6 months of age. For infants 6 months or older, the options for intervention may be considered "more invasive". The purpose of our study is to evaluate outcomes in children with sagittal craniosynostosis treated at Children's Hospital Colorado (CHC) who underwent sagittal strip craniectomy with biparietal morcellation (SSCBM) with no post-operative helmeting. Our aim is to investigate SSCBM as an acceptable alternative for infants up to 1 year of age at time of surgery. Outcomes in cephalic index (CI), a ratio of maximum cranial width over maximum cranial length, are acquired using the 3dMD imaging system, analyzed with Vectra software, and compared to normal values at 6 month and 1 year post-operative time points. The association between age at surgery and change in CI was assessed using a linear model. Results of this study will provide more information about the efficacy and timing of SSCBM without helmeting in the treatment of sagittal craniosynostosis in patients up to 1 year of age at time of surgery.

INTRODUCTION

Sagittal craniosynostosis is the premature fusion of the sagittal cranial suture, and results in biparietal restriction in calvarial expansion during infancy. Patients develop a scaphocephalic appearance due to secondary anterior-posterior elongation, compensatory overgrowth at the non-fused sutures, and occasional morphological asymmetry (Fig. 1). The most common form of premature sutural fusion, sagittal craniosynostosis occurs in approximately 1 in 2500 live births, more commonly affects males, and can be associated with many genetic syndromes, such as Crouzon and Apert syndromes

Surgical intervention for sagittal craniosynostosis has been performed since the early 20th century, with a variety of techniques proposed over the years. Surgical treatments now range from minimally invasive sagittal strip craniectomy with barrel stave osteotomies (SSBS) to the more invasive total cranial vault remodeling (TCV). There has been general agreement that more invasive interventions may be needed for best restoration of normal morphology and for future development. Currently there is no established standard and both type of surgery and timing remain controversial. The best outcomes are thought to follow SSBS when performed before 6 months of age. For infants older than 6 months, TCV is often indicated.

This investigation evaluates the outcomes of children with sagittal craniosynostosis who underwent sagittal craniectomy with biparietal morcellation, as described by Greene and Winston in 1988.

METHODS

Outcomes are based primarily on the cephalic index (CI), a ratio of maximum cranial width over maximum cranial length. Demographic and clinical characteristics were compared between the two age groups using Fisher's exact tests and two sample t-tests. One way ANOVA was used to determine if there were differences in preoperative cephalic indices (CI) among the three surgery types. A linear mixed model, with a random intercept and preoperative baseline CI term was used to test the interaction between time in months and age group on postoperative CI values. The association between age at surgery and change in CI was assessed using a linear model. Continuous variables were log transformed as necessary. All hypothesis tests were two-sided with significance set at 0.05.

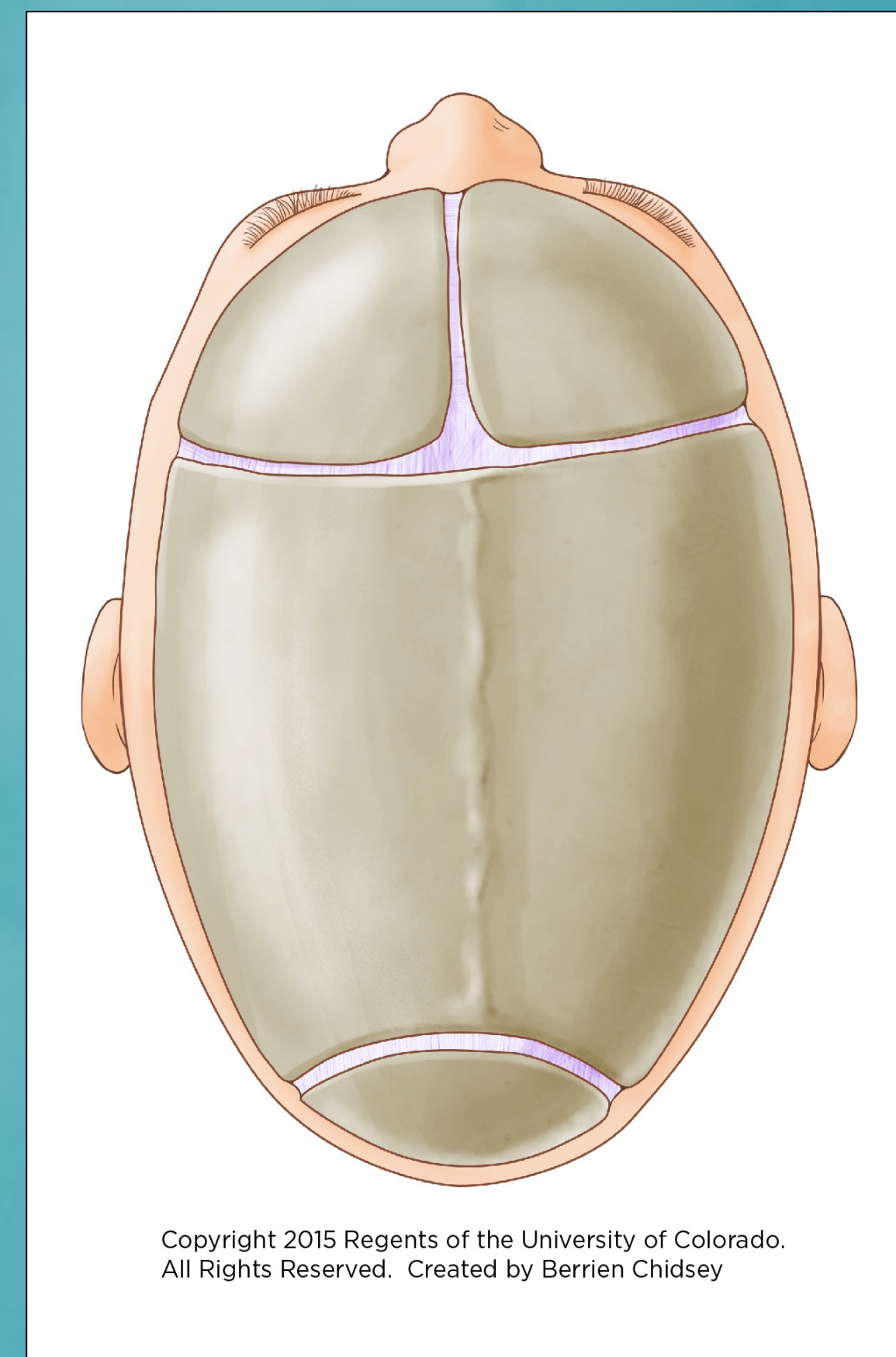
A successful outcome is defined as a post-operative CI within \pm one standard deviation of age-adjusted mean CI. Additional values recorded include intracranial volume, head circumference, blood loss, and length of hospital stay.

Age groups (n = 83):

- < 6 months (52 patients)
- 6 months-1 year (31 patients)

Exclusion criteria:

- Endoscopic correction
- TCV
- Fronto-orbital remodeling
- Post-operative helmeting
- >1 surgery
- Craniosynostosis (non-sagittal)
- Not performed at CHC
- Incomplete patient data
- Unconsented



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Figure 1 – An illustration of the scaphocephalic presentation of sagittal craniosynostosis

Age	Cephalic Index		
	-1 SD	Mean	+1 SD
16 Days-6 Months, ♂	68.7	73.7	78.7
16 Days-6 Months, ♀	68.6	73.3	78.0
6-12 Months, ♂	71.4	78.0	84.6
6-12 Months, ♀	74.0	78.5	83.0
1 Year, ♂	71.8	76.7	81.6
1 Year, ♀	72.6	77.7	82.8
2 Years, ♂	71.8	76.6	81.4
2 Years, ♀	70.4	75.1	79.8

Figure 2 – Average cephalic index in males and females, as reported by LG Farkas & IR Munro in *Anthropometric Facial Proportions in Medicine*, 1987.

RESULTS

➤ Significantly greater gain in CI occurred (78% vs 75%; $p = 0.004$) in the <6m group than in the $\geq 6m$ group at the most recent postop visit. Additionally, the <6m group had a significantly higher change in CI between preop and first postop visit and to the most recent post op visit (8% vs 4%; $p < 0.001$).

➤ Based on a linear mixed model, there was not a statistically significant difference in the rate of post-surgical change between the two groups ($p = 0.49$). When the interaction term for months from surgery and age group are excluded, postoperative CI was -3% (SE: 0.008) lower for patients that were $\geq 6m$ at surgery compared to those that were younger ($p = < 0.0001$). After the initial correction, CI did not change significantly in either group ($p = 0.59$).

➤ The change in CI tended to decrease as age at surgery increased, until age 6 months when the trend leveled off ($p = 0.01$). Up to the age of 6m, there was a -2% (95% CI: -3 to -1%) decrease in change in CI for every month increase in age at surgery ($p < 0.001$). After 6 months of age there was no significant change in CI related to age, 0 (95% CI: -1 to 1%), ($p = 0.909$).

DISCUSSION

We found that, in both our <6m and $\geq 6m$ groups, a large proportion had a normal CI prior to surgery (55% and 63%), indicating that CI did not accurately capture the morphologic differences of their sagittal craniosynostoses. This is consistent with a recent report by Fearon et al. in which a majority of children with sagittal craniosynostosis had a preoperative CI within the normal distribution with no correlation to severity. The CI fails to capture the shape of the forehead resulting in the oversimplification and loss of information that is necessary to characterize the deformity and determine its severity.

Although not a reliable tool to diagnose or determine severity, CI is a useful metric for comparing the amount of correction achieved by different types of surgery and surgeries done at different ages. The greatest change in CI occurred in our younger subjects, with the amount of change decreasing until about 6m of age before plateauing. This decrease in amount of correction obtained with increasing age suggests that surgical correction prior to 6 months of age is preferable. Also patients older than 6 months were more likely to undergo a more extensive surgical correction anterior to the coronal suture with or without additional forehead remodeling. of SSBS. These older patients did not have as large a change in CI, despite having more extensive surgery, but they did have greater change than those who underwent the more common surgery

Future studies should examine the severity of forehead deformity to allow stratification of outcomes and determine the value and indications for remodeling of the forehead in patients with scaphocephaly.