Intraoperative tissue expansion in the surgical correction of craniosynostosis

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BACKGROUND: Wound healing complications can occur after calvarial vault expansion due to tension on the scalp flaps.

OBJECTIVES: To compare wound healing outcomes in patients with craniosynostosis undergoing calvarial vault expansion with and without intraoperative tissue expansion of the scalp.

METHODS: The present analysis was an institutional review board-approved, retrospective cohort study involving 40 consecutive patients at the University of Missouri Hospitals and Clinics (Columbia, Missouri, USA) who underwent calvarial vault expansion for nonsyndromic craniosynostosis between June 1, 2009 and June 30, 2012. Patients were divided into two sequential cohorts: the first 20 underwent calvarial vault expansion without intraoperative tissue expansion; the second 20 underwent calvarial vault expansion with intraoperative tissue expansion. The main outcome measures included presence or absence of wound healing complications (persistent scabbing or slow-healing wounds, hardware exposure, need for operative wound revision or healed but widened scars), with documented postoperative follow-up of at least three months. The primary end point was the presence of a well-healed scar; the secondary end point was the need for an operative revision.

RESULTS: Patients in the intraoperative tissue expansion group had a higher percentage of well-healed scars (73.6%) than those in the nonexpansion group (42.1%) ($P=0.0487$). This difference was primarily due to scar widening in the nonexpansion group.

CONCLUSIONS: The present study demonstrated that the use of intraoperative tissue expansion in patients with nonsyndromic craniosynostosis who underwent calvarial vault expansion resulted in a greater likelihood of a well-healed incision with a lower rate of poor scarring.

Key Words: *Craniosynostosis; Tissue expansion*

Calvarial vault expansion is a frequently performed surgical procedure for craniosynostosis, and its safety is well-supported in the literature (1-3). However, a known possible sequela of this procedure is postoperative wound complication, which may be related to tension on the closure of the coronal incision (3-5). Because the volume of the calvarial vault is purposefully expanded during this surgery, there is also an inherent increase in the surface area, albeit to a lesser degree. Because the soft tissue cover remains the same size, there is often a relative paucity of soft tissue coverage compared with the newly enlarged cranial vault and, thus, the wound closures in these cases are typically under a significant degree of tension. Use of towel clips and other instruments to approximate wound edges for closure can cause scalp trauma. Alternatively, intraoperative tissue expansion of the scalp using a tissue expander recruits additional tissue into the expanded field via mechanical creep for acute wound closure (6,7). The use of tissue expansion is a well-established reconstructive modality in pediatric patients and can potentially provide a means to reduce tension on the

L'expansion peropératoire des tissus pour la correction chirurgicale de la craniosténose

HISTORIQUE : Après une expansion de la calotte crânienne, la cicatrisation peut être compliquée par la tension exercée sur les lambeaux du cuir chevelu.

OBJECTIFS : Comparer les résultats de la cicatrisation chez des patients ayant une craniosténose soignée par expansion de la calotte crânienne accompagnée ou non d'une expansion peropératoire des tissus du cuir chevelu.

MÉTHODOLOGIE : La présente analyse, une étude de cohorte rétrospective approuvée par le conseil d'examen de l'établissement, a été réalisée auprès de 40 patients consécutifs des hôpitaux et des cliniques de l'université du Missouri (Columbia, Missouri, États-Unis) qui ont été soignés pour une craniosténose non syndromique au moyen d'une expansion de la calotte crânienne entre le 1^{er} juin 2009 et le 30 juin 2012. Les chercheurs ont divisé les patients en deux cohortes séquentielles. Les 20 premiers ont subi une expansion de la calotte crânienne sans expansion peropératoire des tissus et les 20 suivants, une expansion de la calotte crânienne accompagnée d'une expansion peropératoire des tissus. Les principales mesures de résultats incluaient la présence ou l'absence de complications de la cicatrisation (gales persistantes ou guérison ralentie, exposition à un corps étranger, nécessité d'une chirurgie corrective ou guérison, mais élargissement des cicatrices), étayée par un suivi postopératoire d'au moins trois mois. Le paramètre primaire était la présence d'une cicatrice bien guérie et le paramètre secondaire, la nécessité de procéder à une chirurgie corrective.

RÉSULTATS : Les patients faisant partie du groupe soigné par expansion peropératoire des tissus présentaient un pourcentage plus élevé de cicatrices bien guéries (73,6 %) que ceux du groupe n'ayant pas subi cette expansion (42,1 %) ($P=0,0487$). Cette différence était surtout attribuable à l'élargissement des cicatrices dans le groupe n'ayant pas subi cette expansion.

CONCLUSIONS : La présente étude démontre que l'expansion peropératoire des tissus chez les patients ayant une craniosténose non syndromique soignés par expansion de la calotte crânienne était plus susceptible de présenter une incision qui guérissait bien et qui cicatrisait mieux.

closure of the coronal incisions performed for calvarial vault remodelling (8). However, performing an additional surgery to expand the scalp skin before calvarial vault expansion could both delay the definitive surgery and expose the patient to the risks associated with an additional surgical procedure with concomitant anesthetic risks. Placement and subsequent removal of a tissue expander during calvarial vault expansion (ie, intraoperative tissue expansion) could diminish tension on the closure and potentially lead to a reduced rate of wound healing complications after surgery, without subjecting the patient to an additional surgery or several sequential clinic visits for expansion. Onishi et al (9,10) have published case reports of such a method. The present article represents the first reported cohort study.

We sought to determine whether intraoperative tissue expansion using a subgaleal tissue expander during calvarial vault remodelling for craniosynostosis results in a greater incidence of well-healed surgical incisions compared with standard incision closure.

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TABLE 1
Wound healing in the nonexpansion group

Patient	Intraoperative expansion	Wound concerns	Surgical correction
1	No	Widened scar	Yes
2	No	Widened scar	No
3	No	Widened scar	No
4	No	Widened scar	No
5	No	Exposed hardware	Yes
6	No	Widened scar	No
7	No	Small wound, no hardware exposed	No
8	No	Widened scar	No
9	No	Widened scar	No
10	No	Parietal wound	Yes
11	No	Widened scar	No
12	No	Well-healed scars	No
13	No	Well-healed scars	No
14	No	Well-healed scars	No
15	No	Well-healed scars	No
16	No	Well-healed scars	No
17	No	Well-healed scars	No
18	No	Well-healed scars	No
19	No	Well-healed scars	No

METHODS

After obtaining institutional review board approval, a retrospective records review of 40 consecutive patients with a diagnosis of nonsyndromic craniosynostosis having undergone calvarial vault expansion between June 1, 2009 and June 30, 2012 by the senior author (ARM), at the University of Missouri Hospitals and Clinics and Women's and Children's Hospital (Columbia, Missouri, USA) was performed. The patients were divided into two sequential cohorts, with the first 20 consecutive patients having undergone calvarial vault remodelling without intraoperative expansion, and the second 20 consecutive patients having undergone calvarial vault remodelling with intraoperative tissue expansion. Inclusion criteria were: a history of nonsyndromic craniosynostosis; at least three months of postoperative follow-up; and a history of calvarial vault expansion at the University of Missouri with or without intraoperative tissue expansion. Exclusion criteria included: intraoperative contamination of the surgical field; postoperative infection; postoperative trauma to the operative site; or the absence of necessary data in the patient's records.

Parameters assessed in all patients included the presence or absence of wound healing complications including persistent scabbing or slow-healing wounds, hardware exposure (only resorbable hardware is used), need for operative wound revision or healed but widened scars. These results were determined from postoperative clinic notes dated at least three months postoperatively, with the primary end point being the presence of a well-healed scar, and the secondary end point being the need for operative revision. A well-healed scar was defined as one without evidence of widening, hypertrophy or breakdown. A widened scar was defined as one with obvious alopecia along all or part of its length, with or without an atrophic appearance. Patients who underwent calvarial vault expansion with intraoperative tissue expansion were compared with patients who underwent calvarial vault expansion without intraoperative tissue expansion. Statistical analysis was performed using the χ^2 test by individuals(s) from the University of Missouri Department of Biostatistics.

Method of tissue expansion

Tissue expansion was performed once or twice during the procedure. First, while the calvarial bone flaps (and bandeau, if fronto-orbital advancement is necessary) were being modified on a separate table, an empty 300 mL standard longitudinally curved tissue expander (Inamed

TABLE 2
Wound healing in the intraoperative expansion group

Patient	Intraoperative expansion	Wound concerns	Surgical correction
1	Yes	Well-healed scar	No
2	Yes	Well-healed scar	No
3	Yes	Well-healed scar	No
4	Yes	Well-healed scar	No
5	Yes	Small scabbed areas initially, ultimately healed well	No
6	Yes	Exposed hardware	Yes
7	Yes	Exposed hardware	Yes
8	Yes	Parietal wound with exposed hardware	Recommended, but no
9	Yes	Exposed hardware	Yes
10	Yes	Well-healed scar	No
11	Yes	Well-healed scar	No
12	Yes	Well-healed scar	No
13	Yes	Well-healed scar	No
14	Yes	Well-healed scar	No
15	Yes	Well-healed scar	No
16	Yes	Well-healed scar	No
17	Yes	Well-healed scar	No
18	Yes	Well-healed scar	No
19	Yes	Well-healed scar	No

Corporation, USA) was placed in the subgaleal plane overlying the intact occipital bone as far posteriorly as possible. At no point was there contact between the expander and any exposed dura. Once the expander was in place, the scalp incision was closed with staples and the expander was slowly inflated by injection with sterile saline. Inflation was continued until the scalp flap began to blanch. The expander was then left in place for a period of at least 15 min or until the bandeau and/or calvarium modifications were complete. Staples and the underlying expander were then removed so that calvarial reconstruction could proceed. At the point of final scalp closure, if significant tension persisted, a second period of tissue expansion was performed in the same manner for a period of 10 min to 15 min. Attention was devoted to reapproximating the galeal layer during closure.

RESULTS

In the group of 20 consecutive patients who underwent calvarial vault expansion without intraoperative tissue expansion (Table 1), the mean age of patients at surgery was 18.3 months, with 11 boys and nine girls comprising the cohort. One patient was excluded for early postoperative wound contamination. Of the remaining 19 patients, eight (42.1%) were noted to have well-healed incisions. Two (10.5%) patients had scabbing/slow-healing wounds, one (5.3%) had minor hardware exposure and eight (42.1%) were noted to have healed but widened scars. Of the 19 patients, three (15.7%) required surgical revision for persistent scabbing or exposed hardware.

In the group of 20 consecutive patients who underwent calvarial vault expansion with intraoperative tissue expansion (Table 2), the mean age at surgery was 22.2 months, with 15 boys and five girls comprising the cohort. One patient was excluded for intraoperative field contamination due to an airway problem. Of the remaining 19 patients, 14 were noted to have well-healed incisions (73.6%). Three of 19 (15.7%) patients required operative revision for minor hardware exposure. One (5.3%) patient was noted to have persistent scabbing without hardware exposure that eventually healed without the need for revision. One (5.3%) patient had persistent scabbing and was noted to eventually develop a parietal wound with minor hardware exposure for which surgical revision was recommended; however,

the patient's family chose not to pursue this revision. No patients in this group were observed to have widened scars. No complications related to the tissue expanders were identified.

The proportion of patients in the intraoperative expansion group with well-healed incisions (73.6%) was significantly higher than the proportion with well-healed incisions in the nonexpansion group (42.1%; $P=0.0487$). In each group, three (15.7%) patients underwent surgical wound revision.

DISCUSSION

One of the complications of calvarial vault expansion is difficulty with wound healing, which encompasses a spectrum ranging from persistent scabbing that ultimately heals, to healed but widened scars, to the development of frank wound formation with underlying hardware exposure requiring operative revision (3-5). The purpose of calvarial vault expansion is to correct the aesthetic deformity of the skull and provide ample room for the developing brain to grow. The volume increase leads to an inherent increase in surface area, and because the soft tissue envelope remains unaltered, incision closure during this procedure can be challenging due to the high degree of tension, sometimes leading to the aforementioned wound healing difficulties. In fact, the degree of tension can be so high that some have been concerned about compression forces on the newly constructed calvarial vault postoperatively (11). We propose that intraoperative tissue expansion in the subgaleal plane is a means to reduce the tension on the closure and thereby reduce the risk of postoperative wound healing complications. Onishi et al (9,10) reported on individual cases of intraoperative tissue expansion for craniosynostosis. Various other forms of intraoperative tissue expansion have been used previously, such as the use of penetrating towel clamps and galeal scoring. However, these methods impart some degree of trauma to the scalp tissues and, in our experience, the use of tissue expanders achieves a greater degree of expansion with less tension on the wound and less insult to the scalp flap. Onishi et al (9,10) performed their tissue expansion before elevating the scalp flap, while in the present study we chose to perform ours mid-procedure during modification of the bandeau and cranial bones on the back table. In either case, no additional operative time is necessary because other activities can be completed during the time of expansion, but in the present study's proposed sequence there is less elapsed time until final closure, allowing less opportunity for the expanded scalp to retract. Certainly any intraoperative expansion presents a favourable time savings relative to returning to the operating room on a subsequent occasion to place a tissue expander to assist with wound closure (5).

Our results demonstrated a statistically significant difference in the rate of well-healed wounds between the intraoperative expansion (73.6%) and nonexpansion (42.1%) groups ($P=0.0487$). There were no widened scars in the intraoperative expansion group versus eight (42.1%) in the nonexpansion group; this finding suggests that intraoperative tissue expansion can play a role in determining the quality of the final scar. There was no difference in the rate of minor wound healing complications requiring operative revision. Subjectively, it has certainly been our experience that wound closure is significantly easier and faster in patients who undergo intraoperative tissue expansion.

The present study's findings must be viewed in light of its limitations. The present study was retrospective in nature, relying on the accuracy of clinical documentation. Second, the sample size may not be sufficiently large to demonstrate differences in the rate of operative revisions for minor wound complications. In addition, the patients in the two groups were not matched according to age, sex, diagnosis or severity of the cranial deformity, although the use of consecutive cases does mitigate selection bias to some degree. Furthermore, the expansion process was not standardized in terms of volume, duration and number of intraoperative episodes of expansion. These variables necessarily change based on clinical assessment of the scalp flap at the time of expansion. Further investigation of this topic would benefit from standardizing these variables. The type of craniosynostosis and

the required reconstruction may also affect the difficulty of wound closure; for example, it is our observation that patients with metopic craniosynostosis typically present more difficult incision closures than patients undergoing reconstruction for sagittal craniosynostosis. Finally, tension is only one contributor to wound healing difficulty. Infection, in particular, is a well-known detractor of any surgical wound healing and has been frequently cited in previous reports on cranial vault expansion (3,5,11-14). We attempted to exclude this variable by excluding patients with clinical infection and identifiable breaches of the sterile field from the study, but it is possible that sub-clinical infection may have contributed to some proportion of our wound healing complications. A more rigorous study, with larger, matched cohorts and randomization to either intraoperative tissue expansion or standard closure would allow for more definitive evaluation of the impact of intraoperative tissue expansion on wound healing in calvarial vault expansion. Finally, a comparison of the average costs of intraoperative tissue expansion with standard wound closure, including the costs associated with any postoperative wound complications or revision procedures, would be informative in future studies.

In the present study, patients who underwent intraoperative tissue expansion during calvarial vault expansion had better final scars than those who did not exhibit intraoperative tissue expansion. The intraoperative expansion group had fewer overall postoperative wound concerns, and the number of patients with well-healed scars was significantly higher in the intraoperative expansion group (73.6% versus 42.1%; $P=0.0487$). The most common wound concern in the nonexpansion group was a healed but widened scar (42.1%), whereas none of the patients who experienced intraoperative tissue expansion were noted to have widened scars. Intraoperative tissue expansion did not add any time to the surgical procedure nor did it lead to any complications. There was no significant difference between the groups with respect to the number of patients requiring operative revision of their coronal incision (15.7% in both groups). Thus, intraoperative tissue expansion during calvarial vault expansion may increase the likelihood of a well-healed incision and requires only a simple, safe, additional step that can be performed concomitantly with other portions of the procedure.

DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES

- McCarthy JG, Glasberg SB, Cutting CB, et al. Twenty-year experience with early surgery for craniosynostosis: I. Isolated craniofacial synostosis – results and unsolved problems. *Plast Reconstr Surg* 1995;96:272-83.
- Maugans TA, McComb JG, Levy ML. Surgical management of sagittal synostosis: A comparative analysis of strip craniectomy and calvarial vault remodeling. *Pediatr Neurosurg* 1997;27:137-48.
- Seruya M, Oh AK, Boyajian MJ, et al. Long-term outcomes of primary craniofacial reconstruction for craniosynostosis: A 12-year experience. *Plast Reconstr Surg* 2011;127:2397-406.
- Cohen SR, Maher H, Wagner JD, Dauser RC, Newman MH, Muraszko KM. Metopic synostosis: Evaluation of aesthetic results. *Plast Reconstr Surg* 1994;94:759-67.
- Pearson GD, Havlik RJ, Eppley B, Nykiel M, Sadove AM. Craniosynostosis: A single institution's outcome assessment from surgical reconstruction. *J Craniofacial Surg* 2008;19:65-71.
- Manders EK, Schenden MJ, Furrey JA, Hetzler PT, Davis TS, Graham III WP. Soft-tissue expansion: Concepts and complications. *Plast Reconstr Surg* 1984;74:493-507.
- Radovan C. Tissue expansion in soft-tissue reconstruction. *Plast Reconstr Surg* 1984;74:482-90.
- LoGiudice J, Gosain AK. Pediatric tissue expansion: Indications and complications. *J Craniofacial Surg* 2003;14:866-72.
- Onishi K, Maruyama Y, Seiki Y. Intra-operative scalp expansion for wound closure without tension in craniosynostosis operation – technical innovation. *J Craniomaxillofac Surg* 1995;23:317-20.

10. Onishi K, Maruyama Y, Sawaizumi M, Iwahira Y, Seiki Y. Usage of intra-operative scalp expansion for primary wound closure in cranio-facial operation. *No Shinkei Geka* 1997;25:795-800.
 11. Eppley BL, Morales L, Wood R, et al. Resorbable PLLA-PGA plate and screw fixation in pediatric craniofacial surgery: Clinical experience in 1883 patients. *Plast Reconstr Surg* 2004;114:850-6.
 12. Tharanon W, Sinn DP, Hobar PC, Sklar FH, Salomon J. Surgical outcomes using bioabsorbable plating systems in pediatric craniofacial surgery. *J Craniofacial Surg* 1998;9:441-4.
 13. Breugem CC, van R. Zeeman BJ. Retrospective study of nonsyndromic craniosynostosis treated over a 10-year period. *J Craniofacial Surg* 1999;10:140-8.
 14. Ahmad N, Lyles J, Panchal J. Outcomes and complications based on experience with resorbable plates in pediatric craniosynostosis patients. *J Craniofacial Surg* 2008;19:855-60.
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