Endoscopic sagittal strip craniectomy

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Vicari in 1994 [1] and Drs. Barone and Jimenez in 1998 [2] introduced endoscopic-assisted craniosynostosis surgery followed by the application of a cranial remolding helmet. Over the years, the results have proven durable.

Following endoscopic sagittal strip craniectomy, in the early postoperative period, the cephalic index growth curve has 4 phases: initial rapid expansion early and late slowed expansion, and plateau, followed by possible regression phases. This highlights the importance of early postoperative cranial remolding orthosis initiation, cranial remolding orthosis compliance, and properly fitting cranial remolding orthosis, especially in the first 2 phases. This data sets the stage for investigating the ideal treatment length [3]

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 a study of Zubovic et al. 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.

They performed a retrospective analysis of data obtained from 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 of 1 year of follow-up. Inpatient charges, physician fees, helmet charges, and outpatient clinic visits in the 1st year were analyzed.

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). : 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 [4].

The endoscopic method is a low-invasive technique used for surgical correction of craniosynostosis, which should be preferred for treating this pathology in children [5] [6].

Open and endoscopic-assisted surgeries have led to increasingly successful management of this condition. Following surgical reconstruction, subsequent development of postnatal synostosis of previously patent sutures have been described and noted to be most frequently associated with multisuture synostosis patients with syndromic diagnoses. Very rarely, postsurgical new sutural fusion has been identified in nonsyndromic patients who initially present with isolated single-suture synostosis.

Three (2.1%) of 145 patients undergoing open craniosynostosis surgery and 2 (1.7%) of 121 patients undergoing endoscopic surgery developed delayed fusion of an additional suture during follow-up. This was identified at a median of 16.4 months after initial surgery in the open group and 15.25 months after surgery in the endoscopic group. In patients undergoing open surgery, each patient developed new sagittal synostosis after initial presentation of coronal synostosis in 1 patient and metopic synostosis in 2 patients. In patients undergoing endoscopic surgery, each patient developed new coronal synostosis after sagittal repair.

Management of craniosynostosis has evolved over time with increasing availability of effective and safe treatments. During long-term follow-up, a small number of patients may develop premature closure of a different suture that did not undergo surgical manipulation.

This finding supports the necessity of long-term clinical follow-up and the utility of delayed imaging when clinical suspicion indicates [7].

Reports have described early endoscopic suturectomy as a treatment option for patients with syndromic craniosynostosis, but such patients often require subsequent calvarial remodeling.

Endoscopic strip craniectomy (ESC) with postoperative helmet orthosis is a well-established treatment option for sagittal craniosynostosis. There are many technical variations to the surgery ranging from simple strip craniectomy to methods that employ multiple cranial osteotomies.

It was proposed in 1998 by D. Jimenez and C. Barone [8].

Advantages are reduction of the blood loss caused by conventional reconstruction, reduction of the incision size, surgery duration, and hospital length of stay.

Endotracheal anesthesia

Supine position with the head flexed forward to a maximum possible angle.

It is most convenient to use the main endoscopic instrumentation for a patient lying in this position.

C-shaped silica gel head supports to ensure convenient head positioning. This provide a sufficient level of head fixation in the proper position. An important issue is prevention of bed sores and injuries from surgical electrodes. For this purpose, disposable sticky electrodes that ensure the maximal contact surface area with child’s skin and isolation can be used.

Another important thing is to control of child’s body temperature. Various body warming systems can be used to maintain the normal body temperature.

An important step in preparing for the surgery is to mark the surgical site.

A median cranial line (a projection of the sagittal sinus), the coronal suture, anterior fontanel (if it is present), and external occipital protuberance are used as the main landmarks.

Proper fixation of the surgical clothing is needed to prevent overlying and traction of the soft tissues in the projection of intervention, to prevent restriction of freedom of surgeon’s actions.

The next step of the surgery is the installation of a special mounting system with adapters for retractor.

Skin incision is made 1.5–2 cm posterior from the coronal suture or anterior fontanel (if it is not closed).

The possible damage to the large terminal branches of the superficial temporal artery should be avoided to prevent intense bleeding.

An additional incision can be made in the projection of the point at the intersection of the lambdoid suture and median (sagittal) line. S-shaped incisions can be made instead of linear incisions due to fact that they are more cosmetic and can be better hidden under hair.

Bone resection can be performed by the subperiosteal method.

The periosteum is stripped with a common raspatory in the incision projection by 1.5–2 cm in the anterior direction to visualize the coronal suture, which is a jagged line in front of the pathological sagittal suture. It can also be projected as a diagonal of the rhombus of the anterior fontanel perpendicular to the sagittal line and can be used as an additional landmark. It is extremely important to avoid damaging skin when using raspatories.

The periosteum is detached in the projection of the sagittal suture and at 3–4 cm to the sides, as well as in the projections of the coronal and lamdoid sutures on both sides (3–4 cm wide).

No large-scale detachment of the periosteum is needed (it may cause additional hemorrhage). The stenosed sagittal suture is defined as an area with bone hyperostosis; its relief can be palpated; there is no broken line typical of the serrate suture at the conjunction of two bones.

A trephination aperture 0.5 cm in diameter can be made by 1.5–2 cm in the posterior direction from the coronal suture and 1.5–2 cm in the lateral direction from the sagittal line using a high-speed drill equipped with a special burr.

The cutting edge of the burr in proper position prevents damage to the scleromeninx.

After making the trephination aperture, the bone is punched using bone forceps in the incision projection. If the anterior fontanel is present, there is no need in perforating the trephination aperture. In this case the scleromeninx can be dissected from the bone in the projection of the anterior fontanel. An important action during the surgery is detachment of the dura mater from inner surface of bones in the craniotomy area. The dura mater is often rigidly attached near the cranial suture; quite large emissary veins are sometimes present. There is a risk of damaging the sagittal sinus when detaching the dura mater from the bone. Under endoscopic visualization, the sagittal sinus always has a medial position and appears as a long dome-like formation. Sometimes a low blood flotation can be observed due to pulsation of brain vessels. Under inner-side visualization, the surfaces of parietal bones in its projection protrude into the skull cavity. One should also bear in mind that in 76% cases the sinus has lateral protrusions (lacunas 2–4 cm and 1.5–2.5 cm wide). The most typical lacuna localizes in the parietal area near the medial edge of the central gyrus [9].

Additional difficulties when the dura mater is dissected emerge when anterior fontanel is present. In this case, fontanel tissues participate in fixation of the dura mater to bone edges. A Polenov guidewire and a Penfield dissector is used to detach the dura mater from bone. These tools are used in all cases to perform dissection at the area required for resection without damaging the dura mater. The dura mater is detached along all the sagittal, coronal and lambdoid sutures. Detachment of the dura mater near the skull base was performed using a raspatory with wide cutting edge under endoscopic control, since the dura mater here is rigidly attached to the bones. The subsequent manipulations are performed under endoscopic control.

Scalp structures in the projection of the resected suture were moved upward.

It is important to control the child’s head position. The most convenient is the endoscope position in a plane parallel to the bone suture and moving the operating unit along the suture during bone resection. Osteotomy was performed along the sagittal suture from its intersection with the coronal suture to the lambdoid suture; the average resection width was 3.57±1.38 cm. In order to obtain additional mobilization, paracoronal osteotomy was performed in several cases in a posterior direction from the coronal suture until the skull base with resection of a part of the greater wing of sphenoid bone and paralamboid osteotomy anterior to the lambdoid suture until its intersection with the parietotemporal suture at both sides.

Notably, there are no known landmarks today to define osteotomy borders. The sagittal sinus is used as a landmark to dissect the sagittal suture, but there are no clear landmarks for additional osteotomies. A special landmark to define the borders of additional bone resection was the greater wing of sphenoid bone. It was partially removed using a high-speed drill and a diamond burr.

The osteotomy area here is limited by posterolateral (temporal) surface of the greater wing of sphenoid bone. It is slightly concaved and is involved in the formation of a wall of the temporal fossa. The lower part of this surface is limited by the infratemporal crest. One needs to keep in mind that in 51% of cases, arteries localize in the osteal canal in the anteroinferior part of the sphenoid bone [10].

The hemorrhage is stopped by bipolar coagulation and applying bone wax. At this stage, an important advantage of rigid fixation and endoscopic control can be seen: the possibility to perform manipulations with both hands (bimanually). A point before the intersection with the parietotemporal suture was used as a landmark of the border when conducting paralambdoid osteotomy.

Hemostasis is another important problem. Hemostasis should be performed at each stage during the surgery. Bones of the cranial base and vault are characterized by a sponge structure and intense blood supply.

Large emissary veins often lead to the dura mater; coagulation is needed if they are revealed. Another important feature of venous component of the cranial vault is the presence of intraosteal venous system localized in the spongy bone layer together with the external (intracutaneous) venous system. These systems are tightly interconnected and interact with the deep venous system localized between the dura mater layers [11].

Bone wax and treatment of the bone edge using a high-speed drill with a diamond tip can be used to stop bone bleeding. Another well-known technique is the use of an aspirator with bipolar coagulation. The use of this tool allows one to stop bone bleeding. However, when using it in hemostasis it is extremely important not to damage and not to coagulate the dura mater; a brain spatula is used to protect it. This method is of best choice in the youngest children, when bones are thin. It is also possible to use such hemostatic agents as SURGIFLO Hemostatic Matrix (Ethicon LLC). Hemostasis is performed under the endoscopic control. An endoscopic retractor is removed after the hemostasis was thoroughly performed. Only resorbable material is used for sealing due to the small size of incision, low tissue mobility in this area, and good healing. The wound is sealed with intracutaneous sutures; the surface is treated with sterile medical glue Dermabond Pro Pen (Ethicon LLC, USA) (Fig. 7). Wound condition is monitored during the hospitalization period. The mean duration of surgery for sagittal craniosynostosis was 163.3±43.25 min. Blood loss was 103.46±58.43 ml and increased with child’s age. Patients stayed in the Resuscitation Department for less than 1 day. Control CT followed by 3D skull reconstruction was performed 1–2 day after surgery. In all cases, no damage to the dura mater, sagittal sinus, air embolism were detected. Neither inflammation, nor infection complications, nor postoperative wound inconsistency were observed. There was no need for puncture in the intervention area. The length of a hospital stay after endoscopic cranioplasty was 3.1±0.5 days. Therefore, endoscopic surgical treatment of scaphocephaly was performed in 20 children. Treatment results were estimated after 1, 3 and 6 months in dynamic follow up according to the CT scanning followed by 3D reconstruction of the skull and anthropometric measurements. An orthotic helmet (“helmet therapy”) was used after regression of postoperative swelling of soft tissues in order to ensure additional correction of the head shape and for protection. The CT and 3D reconstruction data were used to calculate the cranial (cephalic) index for unbiased estimation of treatment results. In the dynamic follow-up after 6 months, the cephalic index was 77.29±4.17 (being 67.84±7.45 at hospitalization), which was considered to be an efficient outcome of intervention. These values, as well as the CT and 3D reconstruction data were used to determine the duration of wearing a helmet. The comparison of the preoperative cephalic index with the data from control examination revealed significant differences (U-test, $p<0.01$)

The possibilities of modern endoscopic tools and instrumentation allow one to perform successful surgical treatment for scaphocephaly. Endoscopic cranioplasty for correction of scaphocephaly is a low-invasion method to treat patients with this pathology.

In contrast to the conventional approaches, this method lowers the risks of complications connected with the volume of surgical interventions due to its low-invasiveness. Since the method is low-invasive, there is no need for long hospital stay [12].

Retrospectiv Reviews

A single-institution retrospective review was performed for patients with MC and SC who underwent ESC from November 2015 to 2019. Patients received preoperative, postoperative, and post-band 3-dimensional imaging. Factors recorded included patient sex, insurance type, number of helmets needed, age at surgery, time of first helmet, and at time of completion of helmet therapy, cephalic index, interfrontal angle, and cranial vault asymmetry index.

Results: Patients with SC and MC had ESC surgery at 3.3 and 3.4 months of age, respectively.Patients with SC were found to have completed banding therapy at a younger age (7.88 versus 10.0 mo), with shorter duration (4.17 versus 6.00 mo), and less number of bands (1.54 versus 2.21) than patients with MC. After regression analysis, suture type was found to be a significant predictor of total time in band therapy (P=0.039) with MC requiring a longer duration of banding therapy when compared with SC.

Suture type directly correlates with duration of helmeting therapy for patients, with patients with MC requiring longer periods of postop helmeting and increased number of bands as compared with SC [13].

Case series

Endoscopic strip craniectomy case series.

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