Surgical Aspects of Endoscopic Treatment of Sagittal Craniosynostosis (Scaphocephaly) in Children

A.A. SUFIANOV, S.S.-H. GAIBOV, R.A. SUFIANOV

Federal Center of Neurosurgery, Ministry of the Health of Russian Federation, Tyumen, Russia

The article focuses on surgical treatment of sagittal craniosynostosis in children. Sagittal craniosynostosis (scaphocephaly) is the most common nonsyndromic monosynostosis. Treatment of children with craniosynostosis should be started as early as possible. Endoscopic method is a low-invasive technique in surgical correction of craniosynostosis. This article describes the features of surgical treatment at all stages of the endoscopic cranioplasty. The data presented are based on the experience of treating 20 children with primary sagittal craniosynostosis. Treatment was performed using endoscopic techniques and special tools designed for endoscopic cranioplasty.

Keywords: nonsyndromic craniosynostosis, scaphocephaly, endoscopic cranioplasty.

Sagittal craniosynostosis is the most common non-syndromic monosynostosis. Its incidence rate ranges from 0.2 to 1 per 1000 liveborn infants, being 40–60% of all nonsyndromic forms [6, 7]. Relationship to gender is observed: 70–90% of all cases are found in boys [6]. Treatment of children with craniosynostosis should be started at young age [2, 4]. Therefore, it is strongly desirable to use low-invasive techniques. The endoscopic method is a low-invasive technique used for surgical correction of craniosynostosis, which should be preferred for treating this pathology in children [3, 4]. Description of surgical aspects of endoscopic treatment in children is of high practical relevance due to the availability of this method and high incidence of of scaphocephaly among nonsyndromic monosynostoses.

This work was aimed at studying surgical features at all stages of endoscopic treatment of sagittal craniosynostosis.

Material and Methods

Endoscopic cranioplasty was performed in 20 children with primarily detected sagittal craniosynostosis. All children were routinely examined following the standard procedures approved for craniosynostosis in our clinic, comorbidities were analyzed, and the neurological status was estimated in accordance to child’s age. CT followed by 3D skull reconstruction was performed in all patients; its results were used to detect abnormalities typical of scaphocephaly; craniometric measurements were made. Treatment was performed using endoscopic technique; special tools designed for endoscopic cranioplasty were used: endoscopic retractor (Dura-Scalp Retractor acc. to JIMENEZ, Karl Storz) with a rigid 4 mm endoscope (Forward–Oblique Telescope Hopkins II, Karl Storz) 0° and 30° and two 5 and 10 mm wide exchangeable extendable plates (Fig. 1). The endoscopic retractor was fixed in

![Fig. 1. Endoscopic retractor (Dura-Scalp Retractor acc. to JIMENEZ, Karl Storz).](image)

a – 4 mm endoscope (Forward–Oblique Telescope Hopkins II, Karl Storz) 30°; b – assembled retractor (ready to be used).
the chosen position with a special rigid mounting system equipped with an adapter (KS-Lock, Karl Storz) (Fig. 2a). A kit of curved raspatories of different curvature and shape of the operating unit and a bone cutting kit were used to dissect soft tissues and resect bones (Fig. 2b). A multifunctional endoscopic unit (Karl Storz) equipped with a H3-Z Full HD camera (Karl Storz) to transmit the image was used for imaging (Fig. 3a). Gel head supports of different shapes were used for convenient positioning of child’s head (Fig. 3b). Comprehensive photo- and video-recording of the key moments of intervention was performed at all stages of surgery in accordance with ethic principles.

Results and Discussion

Cranial deformities have always attracted scientists’ attention. Hippocrates has mentioned the tower-like shape of the head in his manuscripts; he regarded to it as a constitutive abnormality and presumed that there was an association between this abnormality and the cranial sutures [6]. In 1791, S. Soemmering, a German physiologist, anatomist, and anthropologist, admitted that premature fusion of the cranial suture played a significant role in pathogenesis of craniosynostosis. It was Rudolf Virchow who further advanced the fundamentals of modern knowledge of craniosynostosis development in 1851. He postulated that stricture formation of the cranial suture causes restriction of cranial growth in the direction perpendicular to the axis of the damaged suture (the Virchow’s rule) [6]. Notably, craniosynostosis was earlier considered to be an incurable disease and was not of no interest for surgeons. Currently, taking into account the modern methods for diagnostics and treatment, the tactics for this pathology have been significantly changed. There is a clear trend for early diagnosis; earliest possible correction of craniosynostosis is considered to be crucial. Over than a century of surgical treatment of this pathology, multiple surgical techniques have been proposed for different types of craniosynostosis; some of them have been proposed by Russian surgeons. Several of these methods are still used in clinics. Surgery of sagittal craniosynostosis has a long history. The first surgeries of this type (linear craniotomies) were performed by Lanne-
2) facilitation of the formation of skull shape by rapidly growing brain: residual bone defects are healed easier in younger children. In our opinion, craniosynostosis should also be corrected as early as possible. Endoscopic cranioplasty is the method for removing open surgery artifacts. It was proposed in 1998 by D. Jimenez and C. Barone [5]. It is noteworthy that the first treatment of craniosynostosis was performed in a patient with sagittal craniosynostosis in a same manner as over 100 years ago. Other advantages are reduction of the blood loss caused by conventional reconstruction, reduction of the incision size, surgery duration, and hospital length of stay.

In the present study, scaphocephaly was detected in 20 children (18 boys and 2 girls) out of 40 children with craniosynostoses. The mean age of patients was 10.05 months. There were 16 (80%) of patients under 1 year of age (mean age was 5.81±3.02 months); this age was considered to be optimal for endoscopic treatment. CT followed by 3D reconstruction of the skull was used to perform craniometric measurements and to analyze the cephalic index, which was 67.84±7.45 on average. This value is a criterion of dolichocephaly, one of the manifestations of sagittal craniosynostosis. Endotracheal anesthesia was used to fix a child on the operating table. In all cases, the 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. The artificial lung ventilation data were used to monitor the adequacy of head position. Moreover, child’s body position was adjusted using surgical table handles. No special tools were used for head fixation; C-shaped silica gel head supports were used to ensure convenient head positioning. This provided 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 were used. Another important thing is to control of child’s body temperature. Various body warming systems (WarmTouch WT-5900, Covidien AG, USA; Thermomatress Bioterm 5-U, Russia) were 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 were used as the main landmarks. In all cases, the surgical site was treated with iodopyrone and alcohol. 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. We fixed the surgical clothing along the border between the facial and cerebral head sections, leaving the cranial vault uncovered.

The next step of the surgery was the installation of a special mounting system with adapters (KS-Lock, Karl Storz) for an endoscopic retractor. This system allows...
one to fix the retractor in the selected position and easily adjust it, thus changing the view angle in the wound. 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. In our study, the anterior fontanel was opened in 6 children with verified scaphocephaly. The median line of the incision coincided with the sagittal suture and median (sagittal) line. S-shaped incisions were made instead of linear incisions due to fact that they are more cosmetic and can be better hidden under hair; incisions were no longer than 4–5 cm. Bone resection was performed by the subperiosteal method. The periosteum was 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 was 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 lambdoid 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 (Fig. 4). A trephination aperture 0.5 cm in diameter was 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 (Midas Rex Legend EHS Surgical Drill, Medtronic) equipped with a special burr (Match Head Fluted, Medtronic). The cutting edge of the burr in proper position prevents damage to the scleromeninx.

After making the trephination aperture, the bone was 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 [1]. Additional difficulties when the dura mater is dissected emerge when ante-
rior 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 were used to detach the dura mater from bone. These tools were used in all cases to perform dissection at the area required for resection without damaging the dura mater. The dura mater was detached along all the sagittal, coronal and lambdoid sutures. Detachment of the dura mater near the skull base was performed using a raspator with wide cutting edge under endoscopic control, since the dura mater here is rigidly attached to the bones.

The subsequent manipulations were performed under endoscopic control (Fig. 5). 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 paralambdoid osteotomy anterior to the lambdoid suture until its intersection with the parietotemporal suture at both sides. The resection volume was 1.45±0.12 and 1.69±0.63 cm, respectively.

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 was 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 [1]. 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 (Fig. 6).

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 intraostea 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 [1]. 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 craniocynostosis 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 reconstruction of skull was performed 1–2 day after surgery. In all cases, no damage to the dura mater, sagittal sinus, air embolism were detected. Neither inflam-
Fig. 7. Types and methods of hemostasis in endoscopic cranioplasty.

a – the use of SURGIFLO Hemostatic Matrix (Ethicon LLC); 1 – view after applying the matrix; b – hemostasis with bone wax; 2 – spatula; c – the use of an aspirator with bipolar coagulation; 3 – aspirator coagulator; d – view of the postoperative wound treated with sterile medical glue Dermabond Pro Pen (Ethicon LLC, USA); 4 – incision area.

mation, 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 re-gression 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 com-
parison of the preoperative cephalic index with the data from control examination revealed significant differences (U-test, $p<0.01$) (Fig. 8).

**Conclusion**

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.

**REFERENCES**


**Commentary**

The article is devoted to the relevant problem of surgical treatment for sagittal craniosynostosis in children. The purpose of the study was to analyze the features of endoscopic surgical treatment in children with scaphocephaly.

A total of 20 patients with sagittal craniosynostosis were analyzed. The equipment for these surgeries was thoroughly described. The stages and technical features of the surgery, as well as the anatomical landmarks, were precisely described.

The method proposed by D. Jimenez and C. Barone and described in the study has been widely used over the past 16 years. The method consists in performing craniotomy with endoscopic assistance through small incisions of soft tissues. During the surgery, the cranial vault is resected in projection of the synostosed suture with formation of a linear bone defect. Similar surgeries were performed without endoscopic tools in the early XX century and were considered to be low-efficient. Hence, there was a demand for developing reconstructive surgical techniques to be used in patients with craniosynostoses. Development of the methods for orthopedic correction of skull deformities using cranial orthoses (helmets) allowed one to return to using the craniectomy methods.

Therefore, treatment of patients with craniosynostoses yields good results neither when using the conventional cranietomy nor when using the endoscopic assistance modification. This was also proved by an analysis of the unsuccessful results by D. Jimenez and C. Barone who had developed this technique. The main reason for bad results was the lack of orthopedic treatment. Thus, it is more correct to talk about complex surgical and orthopedic treatment of patients with craniosynostoses.

The radiography protocol (in particular, CT) was used in the study; 3D anthropometric measurements were performed. The evidential basis of the study relies on measurements performed using 3D CT reconstruction images. The use of X-ray computed tomography causes significant radiation exposure of young child’s brain and should not be used as a routine control technique; it is used only in the presence of indications.

Craniometric parameter (the cranial index) was used to evaluate the intervention efficiency. The results were statistically analyzed. Statistically significant differences were found in patient groups before and after the treatment, which led to a conclusion about sufficient efficiency of the surgeries. The
cranial index should be used beyond any doubt to assess the treatment results in patients with scaphocephaly, which was also proved by the literature data.

The features of surgical technique that differs from the previously described one are of especial interest: the use of the rigid fixation system for an endoscope with a retractor, which would enable bimanual performing of the surgery; subperiosteal bone resection in the area of the synostosed suture with forceps. Hemostasis methods that are of high importance when performing such surgeries have been described.

Future research should address long-term results of craniectomy with endoscopic assistance. This will allow one to specify indications for treatment and efficiency of the method for treating patients with craniosynostoses.

L.A. Satanin (Moscow)