Intraoperative and postoperative complications in the surgical treatment of craniosynostosis: minimally invasive versus open surgical procedures

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OBJECTIVE To compare minimally invasive endoscopic and open surgical procedures, to improve informed consent of parents, and to establish a baseline for further targeted improvement of surgical care, this study evaluated the complication rate and blood transfusion rate of craniosynostosis surgery in our department.

METHODS A prospective complication registration database that contains a consecutive cohort of all pediatric neurosurgical procedures in the authors' neurosurgical department was used. All pediatric patients who underwent neurosurgical treatment for craniosynostosis between February 2004 and December 2014 were included. In total, 187 procedures were performed, of which 121 were endoscopically assisted minimally invasive procedures (65%). Ninety-three patients were diagnosed with scaphocephaly, 50 with trigonocephaly, 26 with plagiocephaly, 3 with brachycephaly, 9 with a craniosynostosis syndrome, and 6 patients were suffering from nonsyndromic multisutural craniosynostosis.

RESULTS A total of 18 complications occurred in 187 procedures (9.6%, 95% CI 6.2–15), of which 5.3% (n = 10, 95% CI 2.9–10) occurred intraoperatively and 4.2% (n = 8, 95% CI 2.2–8.2) occurred postoperatively. In the open surgical procedure group, 9 complications occurred: 6 intraoperatively and 3 postoperatively. In the endoscopically assisted procedure group, 9 complications occurred: 4 intraoperatively and 5 postoperatively. Blood transfusion was needed in 100% (n = 66) of the open surgical procedures but in only 21% (n = 26, 95% CI 15–30) of the endoscopic procedures. One patient suffered a transfusion reaction, and 6 patients suffered infections, only one of which was a surgical site infection. A dural tear was the most common intraoperative complication that occurred (n = 8), but it never led to postoperative sequelae. Intraoperative bleeding from a sagittal sinus occurred in one patient with only minimal blood loss. There were no deaths, permanent morbidity, or neurological sequelae.

CONCLUSIONS Complications during craniosynostosis surgery were relatively few and minor and were without permanent sequelae in open and in minimally invasive procedures. The blood transfusion rate was significantly reduced in endoscopic procedures compared with open procedures.

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KEY WORDS complication; blood transfusion; pediatric neurosurgery; craniosynostosis; endoscopic; craniofacial

CRANIOSYNOSTOSIS occurs in 1:2000–2500 living births and is defined as the premature closure of one or more cranial sutures, causing typical head shapes depending on the affected suture. Several genetic disturbances are identified in syndromic cases of craniosynostosis, but the etiology of single-suture craniosynostosis remains largely unknown.^{17,21} Surgical intervention is needed mainly for cosmetic reasons but also to prevent in-

creased intracranial pressure (ICP) and its consequences, such as neurological and cognitive disorders. Since Lannelongue performed the first operative treatment of craniosynostosis in 1890,¹⁵ surgical methods to treat craniosynostosis have evolved from a diverse spectrum of partial or complete cranial vault remodeling to a relatively simple strip craniectomy.¹⁶

Open cranial vault reconstruction surgery (OCVRS) is

ABBREVIATIONS EACS = endoscopically assisted craniosynostosis surgery; ICP = intracranial pressure; IOC = intraoperative complication; OCVRS = open cranial vault reconstruction surgery; POC = postoperative complication; PRBC = packed red blood cells; TXA = tranexamic acid.

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TABLE 1. Incidence of complications in patients who underwent EACS or OCVRS

Summary of Complications	No. of Complications	% of Total Complications (95% CI)	No. of Complications (%; 95% CI)	
			EACS	OCVRS
IOCs				
Dural tear	8	44 (25–66)	4 (3.3, 1.3–8.2)	4 (6.0, 2.4–15)
Iodine-induced blisters	1	5.6 (1.0–26)	0	1 (1.5, 0.27–8.1)
Sagittal sinus lesion	1	5.6 (1.0–26)	0	1 (1.5, 0.27–8.1)
POCs				
Pulmonary	1	5.6 (1.0–26)	0	1 (1.5, 0.27–8.1)
Infection	6	33 (16–56)	5 (4.1, 1.8–9.3)	1 (1.5, 0.27–8.1)
Blood transfusion reaction	1	5.6 (1.0–26)	0	1 (1.5, 0.27–8.1)
Total	18	100	9 (7.4, 4.0–13)	9 (14, 7.4–24)

Percentages represent the complication rate within the used surgical technique.

a longstanding major surgical procedure. During this procedure access is obtained by a large ear-to-ear incision. A part of the skull is subsequently removed, remodeled, and reshaped to fit the planned head shape. Surgical time varies from 4–6 hours.⁴ In this way, instantaneous volume increase of the intracranial space is established.

Endoscopically assisted craniosynostosis surgery (EACS) is a relatively new technique. The main goal of minimally invasive craniosynostosis surgery is to reduce the morbidity and invasiveness of classic surgical procedures while preserving the same excellent cosmetic and functional outcomes.^{3,11–13}

The question remains whether with the reduction of invasiveness and extent of the procedure there is also a decrease in the rate of complications. A wide range of complication rates exists in the literature. However, these studies mostly focus on one type of craniosynostosis, especially scaphocephaly, or on one treatment, such as open or minimally invasive procedures.^{1,19} Few comparisons have been made between endoscopic and open craniosynostosis surgery.⁸

To compare minimally invasive endoscopic and open surgical procedures, to improve informed consent of parents, and to establish a baseline for further targeted improvement of surgical care, this study evaluated the complication rate and blood transfusion rate of craniosynostosis surgery in our department.

Methods

The treatment of craniosynostosis was provided by the Craniofacial Team of the Medical University Nijmegen. Procedures were carried out by two neurosurgeons alternately and one maxillofacial surgeon. The second neurosurgeon joined the team in 2010. For each patient the inclusion criteria consisted of a confirmed diagnosis of craniosynostosis with the use of conventional multislice spiral CT scans (Siemens Somatom 16). Two types of procedures were performed: endoscopically assisted strip craniectomy followed by helmet therapy, and open cranial vault remodeling. EACS was performed in all patients with nonsyndromic craniosynostosis younger than 6 months. OCVRS was performed in patients only after

the age of 6 months, typically when they were between 8 and 9 months.

Cases of syndromic craniosynostosis were carefully selected, since little is known about the results of EACS in patients with this condition.¹⁰ The main objective in these procedures was to limit further progression of secondary changes due to suture synostosis as an intended part of a potential staged procedure. Cranial vault remodeling was used in all reoperations of syndromic cases.

We performed a retrospective analysis of a prospective database in which all pediatric neurosurgical procedures, demographic information, and complications were listed.²⁷ All pediatric patients who underwent neurosurgical treatment for craniosynostosis between February 2004 and December 2014 were included and gathered in a new database in SPSS (IBM SPSS Statistics for Windows, Version 22.0). Variables that were analyzed were as follows: demographic data, type of procedure, intraoperative complications (IOCs) and postoperative complications (POCs), postoperative hemoglobin level, and transfusion rate. Missing data were retrieved from the patient information system (EPIC). To establish our reoperation rate, follow-up took place until December 2015; reoperations that were performed in this year are not represented in our basic cohort.

Complications were categorized into intraoperative and postoperative and were further split into several subgroups (Table 1). Complications were categorized in the same way as in our earlier work.²⁶ In short, an IOC was defined as “Any adverse event occurring during the surgical procedure from administration of local or general anesthesia to extubation and/or leaving the operation room.” A POC was defined as “Any unfavorable event transpiring within 30 days of surgery.” Intraoperative hemorrhage was defined as unexpected excessive blood loss leading to a need for transfusion due to cardiovascular instability or premature abortion of procedure caused by poor visualization. Pulmonary complications were defined as all pulmonary or bronchial complications with the exception of infections. Dural tear was defined as damage to the dura mater with loss of CSF. A transfusion reaction was defined as any kind of allergic reaction (anaphylactic, thrombocytopenic/hemolytic anemia, skin rash) directly after the

administration of erythrocytes. Iodine-induced blisters and sagittal sinus lesion were incidents and therefore not specifically defined.

Transfusions were administered in the form of packed red blood cells (PRBCs). The threshold for the administration of PRBCs was hemoglobin < 4.5 mmol/L or a hemoglobin drop more than two points with respect to the preoperative value together with clinical conditions of anemia. Our protocol for postoperative intravenous fluids was adapted in September 2012 to diminish the effect of dilution on hemoglobin levels.³ Tranexamic acid (TXA) was given in agreement between the anesthesiologist and surgical team. When needed, 10 mg/kg was given intravenously during the first 15 minutes, followed by continued intravenous infusion of 2.5 mg/kg TXA during the rest of the procedure.

Patients received a fitted helmet 2 weeks after surgery. This helmet was adapted to the growth of the skull by a specialized orthopedic company (ProReva). Although helmet therapy is a significant part of the treatment in patients who undergo EACS, complications related to helmet therapy are not considered in this study for 2 reasons: 1) Helmet-related complications have recently been published by our center.³ 2) These complications do not occur within 30 days after surgery, and therefore they did not meet the criteria for POC in this study.

Confidence interval (95% CI) of a proportion was calculated for the estimates of complications. A univariate analysis, in the form of unpaired t-tests, was used to assess correlation of clinical variables and outcome data and were calculated using SPSS Statistics for Windows, Version 22.0. Significance was set at $p < 0.05$.

Results

From February 2004 until December 2014, 187 craniostomosis procedures were performed: 121 were endoscopically assisted and 66 were open cranial vault remodeling. Scaphocephaly was the most common diagnosis ($n = 93$ [50%]), followed by trigonocephaly ($n = 50$ [27%]) and plagiocephaly ($n = 26$ [14%]). Five patients younger than 6 months of age with syndromic craniostomosis underwent EACS as well. Additional distribution of diagnoses is shown in Table 2.

The mean age at time of surgery was 6.6 months: 3.9 months (SD 1) in the EACS group and 12 months (SD 8.8) in OCVRS. The mean age at time of surgery of patients who suffered from complications was significantly higher than it was in patients who did not suffer a complication: 9.37 months (SD 9.09) ($p = 0.05$, unpaired t-test). Patients who suffered from POCs tended to be younger (mean 5.28 ± 3.35 months) than those who suffered from IOC (mean 12.6 ± 11.0 months), but the difference was not significant ($p = 0.098$, unpaired t-test).

Overall, 18 complications occurred (9.6%) (95% CI 6.2–15). The IOC rate was 5.3% ($n = 10$; 95% CI 2.9%–10%) and the POC rate was 4.3% ($n = 8$; 95% CI 2.2%–8.2%). The complication rate in patients treated by EACS was 7.4% ($n = 9$; 95% CI 4.0%–14%) and that in patients treated by cranial vault reconstruction was 13.6% ($n = 9$; 95% CI 7.4%–24%). No significant difference was found

TABLE 2. Diagnoses in 187 consecutive patients treated for craniostomosis

Diagnosis	No. of Patients	%
Scaphocephaly	93	50
Trigonocephaly	50	27
Plagiocephaly	26	14
Brachycephaly	3	1.6
Complex multisutural	6	3.2
Syndromic	9	4.8
Total	187	100

(chi-square test: 0.17). No learning curve could be identified.

Most complications occurred in patients diagnosed with scaphocephaly ($n = 6$), followed by those with trigonocephaly ($n = 5$) and plagiocephaly ($n = 5$). However, the complication rate was highest in patients with brachycephaly (1 of 3) followed by those with plagiocephaly (5 of 26), trigonocephaly (6 of 50), and scaphocephaly (6 of 93) (Table 3). One complication was registered in a patient with syndromic craniostomosis who was suffering from trigonocephaly in combination with 9p-deletion syndrome.

Ten IOCs occurred, 4 during endoscopic procedures and 6 during open procedures. The most common IOC was a dural tear (8 times), which occurred 4 times during EACS and 4 times during open procedures. This complication was resolved by stitching. Both of the other 2 IOCs occurred during OCVRS and consisted of blisters due to excessive iodination and a drill lesion of the superior sagittal sinus without excessive blood loss (Table 1). None of these complications led to postoperative sequelae.

Postoperatively, 8 complications occurred, 5 after EACS and 3 after OCVRS (Table 3). The most common POC was infection (6 instances), consisting of 2 upper pulmonary tract infections, 2 cases of gastroenteritis (one of which was caused by rotavirus), 1 urinary tract infection, and 1 wound infection. Only the urinary tract infection occurred after OCVRS. In addition to the 2 pulmonary infections, a case of stridor occurred for which reintubation was needed after OCVRS in a patient syndromic craniostomosis (9p-deletion syndrome). One transfusion reaction took place after OCVRS in the form of skin rash after the patient received 30 ml of erythrocytes (Table 1). Total postoperative infection rate was 6 (3.2%) of 187 (95% CI 1.5%–6.8%). None of the listed complications led to morbidity, mortality, postoperative sequelae, or prolonged hospitalization. Table 3 shows the complete distribution of complications by diagnosis.

The mean postoperative hemoglobin level was 5.0 mmol/L (SD 0.78 mmol/L): 5.1 mmol/L (SD 0.82 mmol/L) in the EACS group, and 4.7 mmol/L (SD 0.61 mmol/L) in the OCVRS group ($p < 0.01$). The mean blood loss was 35 ml (SD 28 ml) during EACS and 180 ml (SD 140 ml) during OCVRS. Data on blood loss was unknown in 9 patients—3 in the EACS group and 6 in the OCVRS group. PRBCs were given on the basis of the

TABLE 3. Summary of data in patients who underwent EACS or OCVRS

Variable	No. of Patients	Age (mos)*	No. of Patients (%; 95% CI)			Blood Loss (ml)*	Transfusion Rate†
			IOCs	POCs	Reop Rate		
OCVRS	66	12 ± 8.8	6 (9.1, 4.2–18)	3 (4.5, 1.6–13)	4 (6.1, 2.4–15)	180 ± 140	66 (100%)
Scaphocephaly	30	10 ± 8.9	1 (3.3, 0.59–17)	1 (3.3, 0.59–17)	1 (3.3, 0.59–17)	125 ± 75	30 (100%)
Trigonocephaly	15	10 ± 2.9	2 (13, 3.7–38)	1 (6.3, 1.2–30)	0	218 ± 167	15 (100%)
Plagiocephaly	12	13 ± 9.5	3 (25, 8.9–53)	0	1 (8.3, 1.5–35)	194 ± 124	12 (100%)
Brachycephaly	2	9.9 ± 3.5	0	0	0	110 ± 85	2 (100%)
Syndromal	4	27 ± 12	0	1 (25, 4.6–70)	1 (25, 4.6–70)	431 ± 263	4 (100%)
Multisutural	3	9.0 ± 5.9	0	0	1 (33, 6.2–79)	207 ± 90	3 (100%)
EACS	121	3.9 ± 1.1	4 (3.3, 1.3–8.2)	5 (4.1, 1.8–9.3)	4 (3.3, 1.3–8.2)	35 ± 28	26 (21, 15–30)
Scaphocephaly	63	4.0 ± 1.0	1 (1.6, 0.28–8.5)	3 (4.7, 1.6–13)	1 (1.6, 0.28–8.5)	32 ± 30	18 (28, 19–41)
Trigonocephaly	35	3.6 ± 1.1	0	2 (5.7, 1.6–19)	0	39 ± 25	6 (17, 33–64)
Plagiocephaly	14	3.9 ± 1.1	2 (14, 4.0–40)	0	1 (7.1, 1.3–31)	33 ± 25	0
Brachycephaly	1	4	1 (100, 21–100)	0	0	10	0
Syndromic	5	3.1 ± 1.6	0	0	1 (20, 3.6–62)	64 ± 29	1 (20, 3.6–62)
Multisutural	3	3.6 ± 1.0	0	0	1 (33, 6.2–79)	65 ± 36	1 (33, 6.2–79)

* Values are expressed as the mean ± SD. Counts are expressed as numbers, percentage, and 95% confidence interval for proportions.

† Confidence intervals for transfusion rates in OCVRS are not given since transfusion was a standard part of procedure. For EACS, data are presented as the mean rate (%; 95% CI).

patient's hemoglobin level (< 4.5 mmol/L) and clinical condition. All patients who underwent an open procedure received a blood transfusion intraoperatively. One EACS-treated patient needed an intraoperative blood transfusion. The postoperative transfusion rate in patients treated by EACS was 21% (95% CI 15%–30%) (n = 26). The mean hemoglobin level in these patients was 4.4 mmol/L (SD 0.91 mmol/L). Eight patients (6.6% of total EAC group, 31% of transfusions) in the EACS group received a transfusion despite having a hemoglobin level greater than 4.5 mmol/L (mean 5.4 mmol/L [SD 0.50 mmol/L]). In 4 of these patients the reported reason for transfusion were as follows: tachycardia, fast decline in hemoglobin level, paleness, and excessive comorbidity. In the other 4 patients, the reasons for transfusion were not well defined in the patient records.

The reoperation rate for EACS in patients with nonsyndromic craniosynostosis was very low (2.5% [n = 3]; 95% CI 0.89%–7.3%). One patient treated with EACS for anterior plagiocephaly underwent a procedure for fronto-orbital advancement at a later age in another center, for cosmetic reasons. There is no known information about the reoperation of this procedure in our center. Two other patients, both with nonsyndromic craniosynostosis and both treated for plagiocephaly, displayed a persistent craniectomy gap with outbending of the bony edges, suggesting raised ICP, although no clinical signs or symptoms were present. These patients underwent fronto-orbital remodeling in 2015. One patient with syndromic craniosynostosis, treated for Apert syndrome, underwent a reoperation in the form of OCVRS at a later stage.

In the OCVRS group, reoperation rate was 6.1% (n = 4; 95% CI 2.4%–15%). One of these 4 patients, suffering from 9p-deletion syndrome with trigonocephaly, had bilateral bony bumps on the frontal bone causing pressure

sores after his first operation at the age of 12 months, and he underwent reoperation at the age of 26 months. The other patient, treated for complex multisutural craniosynostosis at the age of 3.3 months, needed a left-sided fronto-orbital advancement to treat right frontal bossing and mild left anterior plagiocephaly when he was 15 months of age. The third patient (with plagiocephaly) suffered from raised ICP (8 mm Hg in the sitting position and 22–24 mm Hg in lying position), as measured with a telemetric ICP-monitoring device (NEUROVENT P-Tel, RAUMEDIC AG), for which posterior OCVRS was performed when the patient was age 38 months. The last patient, diagnosed with scaphocephaly, suffered from a growing skull fracture, in combination with raised ICP; closure of the fracture was performed in a second procedure, and a ventriculoperitoneal shunt was also placed, when the patient was 23 months of age. This procedure was not included in our main database, since this procedure did not meet the criteria for open craniosynostosis surgery. The overall reoperation rate was 4.3% (n = 8; 95% CI 2.2%–8.2%). The total number of complications that occurred during reoperation was 3, all dural tears. However, all 3 procedures were performed after December 2014, and therefore the complications were not registered in our cohort.

Discussion

Both OCVRSs and EACSs were performed in our center. This made it possible to compare both techniques with regard to complications and blood transfusion rates. The blood transfusion rate differed for the two procedures. The IOC rate was higher for OCVRS, but POC rate differed only 0.4% in favor of EACS. The overall complication rates for EACS and OCVRS did not significantly differ, and no learning curve could be identified.

Both IOCs and POCs in craniosynostosis surgery were minor, did not prolong hospitalization, and did not have late sequelae.

In our recent published study, we reported an overall complication rate for all pediatric neurosurgical procedures of 20.2%—a 2.7% IOC rate and a 17.5% POC rate.²⁷ In the present study, specific to craniosynostosis, we found an overall complication rate of 9.6% (95% CI 6.2%–15%), of which the IOC rate was 5.3% (95% CI 2.9%–10%) and the POC rate was 4.3% (95% CI 2.2%–8.2%). The higher IOC rate associated with craniosynostosis surgery is the result of dural tearing, which was the most common complication in craniosynostosis surgery in our center ($n = 8$). The rate of dural tears (4.3%) is comparable to that seen in the literature.^{1,5,6}

The mean complication rates in the OCVRS group in the present study (13.6%, 95% CI 7.4–24) was higher than what has been reported in literature (6.8%),^{1,8,22,25} which is partly the result of syndromic craniosynostosis cases and IOCs having been excluded in these studies. Our complication rate for syndromic cases treated with OCVRS was 25%, but this rate derives from a single complication occurring in a cohort of 4 patients. In a series of 23 syndromic cases treated with OCVRS, Han et al. reported a complication rate of 23% (9 IOCs, of which 7 dural were tears, and 1 POC).⁸ The complication rate associated with EACS in the present study was comparable to what has been reported in the literature.^{8,25} However most of the reports in the literature on complications associated with EACS are limited to sagittal synostosis,^{19,24} with a mean complication rate of 9.8% compared with our 6.3% in patients who underwent EACS for scaphocephaly.

The most common POC was infection. The majority of infections occurred after EACS (Table 1). No causal correlation was found. It is imaginable that, since EACS patients do not go to the intensive care unit after surgery, hygiene in our medium-care unit and according to protocols is less strict than in an intensive care unit. In addition, patients who underwent EACS were significantly younger than those who underwent OCVRS, making them more prone to airway and gastrointestinal tract viral infections.

We also explored the use of EACS in selected syndromic cases at a very early age (< 1 month), not as a definitive treatment but to limit the further progression of secondary changes due to suture synostosis, leaving ourselves the option of performing OCVRS at a later stage (between 6–12 months of age). We suggested that an early opening of the sutures involved can relieve raised ICP and allow for a better brain development until the age that skull remodeling techniques can be carried out to treat all deformities and also to reduce the severity of the deformity in need of reconstruction at the second procedure. Since the EACS is performed at a very early age and does not aim to be a definitive treatment, we did not perform helmet therapy in these cases. Thus, the role of EACS in syndromic cases has not been clearly established, and it will be interesting to see the long-term results in larger groups of patients with syndromic craniosynostosis treated solely by EACS.^{2,8,10}

Our total revision rate was 4.3% (95% CI 2.2%–8.2%):

6.1% (95% CI 2.4%–15%) for OCVRS and 3.3% (95% CI 1.3%–8.2%) for EACS (including syndromic cases). The mean reoperation rate in literature for open procedures is 7.6%.^{7,8,14} Han et al. reported an endoscopic reoperation rate including syndromic cases of 4% and a total revision rate of 7.9%.⁸ One reason for the relatively low revision rate in this study could be that the majority of patients were treated by EACS, since the odds ratio for reoperation in simple strip craniectomy procedures is 0.25 (95% CI 0.05–1.25), while total OCVRS had an odds ratio of 1.39 (95% CI 0.27–7.16).¹⁴ After that, our incidence of syndromic cases in our cohort was slightly lower than the mean incidence in the cohorts described in the literature (7.4% vs 9%).^{7,8,14} Reoperation is correlated with a higher complication rate.^{5,6} In our study, 3 complications occurred during reoperation (38%, 95% CI 14%–69%). Since this is a very small population, nothing can be concluded.

In the EACS group, a clear reduction of blood loss was seen in comparison with OCVRS in our center, as well as in reports in the literature ($p < 0.005$, unpaired t-test).^{3,11–13} This is probably due to the longer surgical time and the extent of the OCVRS.²⁸ Although the postoperative hemoglobin level differed significantly between EACS and OCVRS, the difference in postoperative hemoglobin level was biased by the intraoperative transfusions that were administered to patients during OCVRS. This means that the difference between OCVRS and EACS was underestimated.

Administration of PRBCs is associated with the risk of contamination, acute hemolytic reactions, transfusion-related lung injury, and universal transfusion-related immune modulation.^{18,29} For this reason, it is important to reduce the transfusion rate in the endoscopic as well as in the open remodeling procedures. Because dilution may play an important role in the drop in postoperative hemoglobin level,⁹ and a very strict protocol for the administration of intravenous fluids postoperatively was incorporated in 2012, resulting in a significant decline in transfusion rate to 7.7% in EACS-treated patients.³ What remains to be explored is whether TXA is effective in reducing blood loss and blood transfusion rates in craniosynostosis surgery in our center. TXA is a promising drug that reduces blood loss and/or blood transfusion rates.²³ However, because of our limited experience (only 5 in the OCVRS cohort), we cannot draw any conclusions about the efficiency of TXA in reducing blood loss and/or blood transfusion rate in our center.

Age at time of surgery differed significantly between the endoscopic and open surgery groups (3.9 and 12 months, respectively). This could have led to bias, since interventions in the younger child are more likely to cause complications than interventions in the older child.^{14,20} However, in our study, we found that the younger group, treated with EACS, suffered fewer complications. The reason that our complication rate was highest in our older patients is probably due to the fact that they underwent major surgery compared with the younger patients who received the minimally invasive EACS.¹⁴ Thus, it would seem that the minimal invasiveness and shorter surgical time of this technique outweigh the disadvantages of the younger age.

This study contained a small population, which makes comparisons difficult. Comparisons are even harder to make because of the low complication rates. Definitive conclusions therefore cannot be drawn. Since this was a retrospective cohort study, we did not perform an a priori power calculation.

Selection bias is one of the main risks of bias in our study. However, indications for the types of surgery differ widely, and therefore randomization is not practicable. For this reason, an evaluation with prospective data collection and retrospective analysis was performed.

Complications related to helmet therapy, as mentioned in our previously published study,³ did not occur within 30 days postoperatively. Therefore, these complications did not meet the criteria for POCs in this study. Since helmet therapy is a significant part of the endoscopic treatment, and helmet therapy may cause additional complications that will not occur after open surgery, 30-day complication registration may be a cause of bias favoring endoscopic treatment.

In summary, EACS is a minor surgical intervention with a lower complication rate, although not statistically significantly so in this study, and a low blood transfusion rate in comparison with OCVRS. Therefore, with our current experience, we prefer EACS followed by helmet therapy for most nonsyndromic craniosynostosis patients under the age of 6 months. Based on our limited experience, we believe EACS may also be a meaningful add-on therapy for syndromic cases to relieve the burden on the infant, until definitive reconstructive surgery can be performed at a later age.

Conclusions

Complications during craniosynostosis surgery are relatively few and minor and are without permanent sequelae in open as well as in minimally invasive procedures. We can conclude that in EACS slightly fewer complications occur than in OCVRS. The blood transfusion rate was significantly reduced after EACS. However, more research needs to be done to assess which technique is the most appropriate to provide the best possible care for patients diagnosed with craniosynostosis.

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Disclosures

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Author Contributions

Conception and design: van Lindert. Acquisition of data: Arts. Analysis and interpretation of data: Arts. Drafting the article: Arts. Critically revising the article: van Lindert, Delye. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: van Lindert. Statistical analysis: Arts. Study supervision: van Lindert.

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