Evaluation of anesthesia in endoscopic strip craniectomy: A review of 121 patients

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Objective: The aim of this study was to evaluate pre-, intra-, and postoperative anesthetic parameters in endoscopic strip craniectomy in order to improve anesthesiological care.

Materials and Methods: This is a retrospective patient cohort study of our first 121 patients treated by endoscopic strip craniectomy. Preoperative as well as intra- and postoperative anesthesiological and neurological parameters were analyzed. Furthermore, the need for intensive care unit admission, blood loss, and blood transfusion rate were measured.

Results: The mean age of patients was 3.9 months (standard deviation = 1) at a mean weight of 6.3 kg (standard deviation = 1.3). Comorbidity was registered in 13 (11%) patients of which 5 had syndrome-related comorbidities. Mean duration of anesthesia was 131 minutes (standard deviation = 32). One hundred and sixteen patients were induced by mask induction with sevoflurane and 5 patients were induced intravenously.

Intraoperative hypothermia (between 35 and 36 degrees Celsius) occurred in 10 patients. Mild intraoperative hypothermia (between 35 and 36 degrees Celsius) occurred in 10 patients. One hundred and sixteen patients were induced by mask induction with sevoflurane and 5 patients were induced intravenously.

In 16 patients, brief and small intraoperative oxygen saturation drops were common during this study. No indication for venous air embolism was found based on endtidal CO₂. Postoperative temperature above 38 degrees Celsius occurred in 17 patients. Postoperative pain management was mainly established by paracetamol and low-dose morphine when necessary. No postoperative neurological symptoms were reported and no deaths occurred.

Conclusion: These patients had a relatively short intraoperative course with stable vital parameters during surgery. We report a low incidence of significant venous air embolism, a blood transfusion rate of 21% and only minor perioperative disturbances in vital parameters.

KEYWORDS
anesthesia, craniosynostosis, endoscopy, minimally invasive, neurosurgery, pediatric
1 | INTRODUCTION

Craniosynostosis occurs in 1:2000-2500 living births and is defined by the premature closure of 1 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.  

The most common and familiar technique in the treatment of craniosynostosis is the cranial vault reconstruction technique. This is a major surgical procedure and is associated with long surgical duration, long length of hospital stay, major blood loss, high blood transfusion rates, and the need for intensive care unit admission after surgery. In the past decades, treatment of craniosynostosis has evolved. This led to the development of minimally invasive techniques such as spring-assisted craniosynostosis surgery and endoscopic strip craniectomy. These procedures have a lesser impact on the pediatric patient and are related with short surgical duration, short length of hospital stay, less blood loss, low blood transfusion rates, and no need for admission to an intensive care unit after surgery. Several centers show positive results regarding their anesthesia technique during the treatment of craniosynostosis. However, most studies are limited to 1 or 2 forms of craniosynostosis, especially sagittal synostosis. This study aims to evaluate the main intra- and postoperative anesthetic parameters in endoscopic strip craniectomy followed by helmet therapy for unisutural craniosynostosis, multisutural craniosynostosis, as well as syndromic forms of craniosynostosis. We were particularly interested to know the data about blood loss, duration of surgery, anesthesia and hospital stay, and the need for ICU admission. This research is part of a research project regarding minimally invasive techniques in craniosynostosis surgery in which our operative technique and surgical complications have already been published.

2 | MATERIALS AND METHODS

This is a retrospective study of a well-defined patient cohort in a university hospital performed in accordance to local rules from the institutional ethical committee. Study time ran from August 2005 until December 2014, during this period 121 patients were treated by endoscopic strip craniectomy. Data were retrieved from electronic anesthesia records out of our automatic electronic patient information system EPIC (Epic Systems Corporation (2014), Madison, Wisconsin, USA). Records that dated before the introduction of EPIC were retrieved from NOVAS (NOVAS, Philips) and uploaded into EPIC.

For each patient, the inclusion criteria for endoscopic strip craniectomy consisted of a confirmed diagnosis of craniosynostosis with the use of a conventional multislice spiral CT scan (Siemens Somatom 16, Erlangen, Germany) of the craniofacial skeleton and an age below 6 months at the time of surgery.

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| What is already known |
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| • Minimally invasive craniosynostosis surgery shows significant surgical advantages over open surgical craniosynostosis procedures. |

| What this article adds |
|-----------------------|
| • In this cohort, patients had a relatively short intraoperative course with stable vital parameters during surgery. There was a low incidence of significant venous air embolism, and the blood transfusion rate was 21%. |

The treatment of craniosynostosis was provided by the Craniofacial Team of the Medical University Nijmegen, consisting of 2 pediatric neurosurgeons, 3 pediatric anesthesiologists, 2 maxillofacial surgeons, geneticists, and the technical staff of the 3D-photogrammetry department. Both surgeons and anesthesiologists worked according to a structured protocol for the treatment of craniosynostosis.

Preoperatively, all patients were thoroughly clinically screened by both the anesthesiologist and surgeon. Also preoperative Cephalic Index, 3D photogrammetry, and hemocytometry (hemoglobin, hematocrit, erythrocyte count, MCHC, MCV, MCH, RDW, and thrombocyte and leukocyte count) were performed.

The operation room was checked and prepared according to our protocol for patients under 18 months of age. Anesthesia was induced in supine position with sevoflurane 6% or intravenously with propofol. Two peripheral intravenous cannulae were placed. Thereafter, an i.v. infusion with glucose 3.3% and NaCl 0.45% or later Ringer’s lactate was started and antibiotic prophylaxis was given. Infusion rate was based on the basal fluid need of each patient, which is 4 mL/kg/h for patients with a body weight between 5 and 10 kg according to the Dutch Association of Anaesthesiology (NVA) fluid protocol. Endotracheal intubation was performed after the administration of rocuronium or suxamethonium. Preoperative parameters that were analyzed in this study are: demographic data, length and weight of the patient, comorbidity, American Society of Anesthesiologists (ASA) classification, and hemoglobin and hematocrit serum levels.

Standard intraoperative monitoring was used. The infants diagnosed with trigonocephaly, frontal plagiocephaly, and brachycephaly were placed in supine position, stabilized in a vacuum mattress, with the head contralaterally rotated (in plagiocephaly and brachycephaly) or in a neutral position (trigonocephaly). The most common other position was the sphinx position for scaphocephalic patients, whereby a vacuum mattress was used to support the chin. For the prevention of pressure sores, gel pads were used instead of towels. After achieving the right position, the incision lines were infiltrated with lidocaine (5 mg/mL) with epinephrine (2.5 μg/mL) with a maximum of 4 mg/kg lidocaine. Maintenance of anesthesia consisted of sevoflurane 2%-3% in oxygen/air supplemented with intravenous...
fentanyl. For nausea prophylaxis, 0.1 mg/kg of ondansetron was given i.v.

Intraoperative data were retrieved from the automatically and electronically recorded anesthesia records, including: heart rate, blood pressure, pulse oximetric SpO₂, endtidal CO₂ and endtidal sevoflurane, rectal temperature, fluid losses and replacements, blood loss, and transfusion requirements. SpO₂ and endtidal CO₂ were captured every minute. Hypoxemia was defined as an SpO₂ under 90% for at least 1 minute. Mild hypothermia was defined as a temperature between 35 and 36 degrees Celsius and hyperthermia as a temperature above 38 degrees Celsius. During induction and awakening a heat lamp was used to prevent hypothermia, during the procedure prevention of hypothermia was supported by a forced air convection warmer. EtCO₂ was considered to be normal between 30 and 50 mm Hg. It was read by watching the trend of the etCO₂ graph in order to estimate the mean etCO₂ during the procedure. A sudden drop in etCO₂ in combination with a sudden drop in systolic blood pressure was interpreted as a possible venous air embolism (VAE). A systolic blood pressure between 70 and 105 mm Hg was reported as normal.

Blood loss was estimated by measuring the suction canisters and surgical gauze weighing. The decision to intraoperatively transfuse packed red blood cells (PRBC) was at the discretion of the anesthesiologist and surgeon who based their decision on clinical assessment and blood loss.

In summary, intraoperative variables that were analyzed are: type of induction, position of the patient, position of the tube, temperature, pulse oximetry, etSevo and etCO₂, duration of surgery, duration of anesthesia, blood loss, fluid administration, and pain management.

At the end of surgery patients were extubated and transferred to the postoperative anesthesia care unit (PACU) for a minimum of 1 hour. Postoperative analgesia was primarily achieved with paracetamol 80 mg/kg/d. NSAIDs were not used, deliberately. Continuous morphine infusion was started based on the children’s and infants’ postoperative pain scale (CHIPPS): when the CHIPPS score was higher than 7, morphine was started and when the score decreased, morphine infusion was gradually reduced over time. Morphine was started, when required, at 5 μg/kg/h and increased to maximally 40 μg/kg/h based on the CHIPPS score. Postoperatively, the patients were monitored on the general pediatric ward. According to our postoperative blood transfusion protocol, packed cells were given when hemoglobin levels dropped more than 3 g/dL with respect to the preoperative value in combination with a clinical signs of anemia (eg, pallor of skin and conjunctiva, delayed capillary refill, tachycardia, and tachypnea) and always at the time hemoglobin levels dropped under the 7.25 g/dL. Our protocol for perioperative i.v. fluids was adapted in September 2012 in order to diminish the effect of dilution on hemoglobin levels and to lower the incidence of postoperative hyponatremia. Hypotonic solutions were replaced by isotonic solutions and the perioperative infusion rate was set at 4 mL/kg/h and adapted to 3 mL/kg/h when the patient’s oral intake was sufficient. Postoperative helmet therapy was started at 2 weeks after surgery.

Postoperative parameters that were analyzed are: hemoglobin and hematocrit serum levels, heart rate, blood pressure, respiratory rate, pulse oximetric oxygen saturation, temperature, pain management, and length of hospital stay. Postoperative data that were retrieved are measurements within 24 hours after surgery. Patients were operated in the morning and routine clinical evaluation and laboratory tests were performed in the evening, or the first day postoperatively.

2.1 Statistical analyses

Data were analyzed in IBM spss Statistic Data Editor version 22. Data are presented as mean and standard deviation. No inferential statistics were used.

3 RESULTS

In the study period 121 surgical procedures were performed in 121 consecutive patients (85 males and 36 females). Most patients were diagnosed with scaphocephaly (n = 63, 52%) followed by trigonocephaly (n = 36, 30%). Besides single-suture craniosynostosis, multisutural and syndromic cases (3 Apert and 2 Muenke syndrome) were treated as well (Table 1).

The mean age at time of anesthesia was 3.9 months (SD = 1.1) at a mean weight of 6.3 kg (SD = 1.3). The mean ASA-classification was 1.2 (SD = 0.47). Most patient had an ASA I classification (n = 98), 20 patients ASA II, and 3 patients ASA III. One patient with an ASA III was diagnosed with Apert syndrome with ventricular septal defect, glossopexy, and cleft palate. The other 2 ASA III patients were treated for scaphocephaly of which one was an ex prematurity of 29 weeks who was attended to the neonatal intensive care unit (NICU). The other patient was diagnosed with uncorrected cleft palate in combination with obstructive breathing.

Comorbidities were identified during preoperative screening in 13 (11%) patients of which 5 had syndrome-related comorbidities. Comorbidities consisted of 4 patients with atopy, 3 patients with viral infections (a cold, without hyperthermia), 1 patient with neutropenia, 2 patients with additional facial malformations, 2 patients

| TABLE 1 Patient characteristics per diagnosis. Values are expressed as the mean (with standard deviation) or numbers |
|-----------------|-------|--------|------|-------|
| Diagnosis           | Number | Gender | Age  | Weight |
|---------------------|--------|--------|------|--------|
| Scaphocephaly       | 63     | 50/13  | 4.1 (1.0) | 6.4 (1.3) | 1.2 (0.5) |
| Trigonoccephaly     | 36     | 24/12  | 3.6 (1.1) | 6.3 (1.2) | 1.1 (0.28) |
| Plagiocephaly       | 14     | 4/10   | 3.9 (1.1) | 6.1 (1.4) | 1.2 (0.43) |
| Brachycephaly       | 1      | 1/0    | 4    | 7      | 1      |
| Syndromal           | 5      | 4/1    | 3.1 (1.6) | 6.2 (2.0) | 1.8 (0.84) |
| Multisutural        | 2      | 2/0    | 3.5 (0.95) | 4.4 (1.7) | 2 (0) |
| Total               | 121    | 85/36  | 3.9 (1.1) | 6.3 (1.3) | 1.2 (0.47) |

ASA, American Society of Anesthesiologists.
with cardiac, and 2 with pulmonary-related comorbidities. One patient had correction of esophageal atresia 3 months before endoscopic strip craniectomy for multisutural synostosis. Mean ASA-score in patients with comorbidities was 1.6 (SD = 0.65). None of these comorbidities were associated with anesthesia-related problems.

Preoperative blood pressure was not routinely obtained. First measurement of blood pressure was performed after anesthesia induction with sevoflurane. Therefore, this blood pressure does not represent a true awake blood pressure. One hundred and thirteen patients had intraoperative systolic blood pressures between 70 and 105 mm Hg. In 2 patients, a blood pressure lower than 70 mm Hg was measured. Six patients had a blood pressure above 105 mm Hg.

Mean duration of surgery was 61 minutes (SD = 21). Mean duration of anesthesia was 131 minutes (SD = 32).

Most of the scaphocephalic patients (n = 61) were operated in the sphinx position. The first 2 patients were operated in the supine position, since endoscopic strip craniectomy was new in our center and the sphinx position was not yet been incorporated. The brachycephalic patient was repositioned during surgery from prone position to right lateral tilt position. All other patients were operated in supine position.

One hundred and sixteen patients were induced by mask induction with sevoflurane and 5 patients were induced intravenously with propofol. The preferred position for the endotracheal tube was oral (n = 98), but in 23 cases, a nasal tube was used, mostly in patients suffering from scaphocephaly. Furthermore, 1 patient treated for Muenke syndrome and the brachiocephalic patient were intubated nasally.

Mild intraoperative hypothermia occurred in 10 patients, defined as temperatures between 35 and 36 degrees Celsius. No cases of more profound hypothermia occurred. The mean duration of hypothermia was 62 minutes (SD = 35). None of our patients suffered from intraoperative hyperthermia, ie, temperature above 38 degrees Celsius.

The mean intraoperative blood loss was 5.7 mL/kg (SD= 4) (Table 2). Postoperative blood transfusion within 24 hours after surgery was given in 26 (21.5%) patients, with a mean blood loss of 10.5 (SD = 6.3) mL/kg vs 4.3 (SD = 2.5) mL/kg in the nontransfused group. One patient needed transfusion intraoperatively. Only 1 syndromic patient, diagnosed with Apert syndrome, needed a PRBC. Mean weight in patients that needed transfusion was 6.1 kg (SD = 1.56) vs 6.3 kg (SD = 1.25) in the nontransfusion group and the mean duration of anesthesia in transfused patients was 148 minutes (SD = 30.0) vs a mean of 127 minutes (SD = 30.8) in the nontransfusion group.

Hemoglobin and hematocrit were measured both pre- and postoperatively. In the preoperative measurements, 13 hemoglobin measurements and 15 hematocrit measurements are not included due to missing data. The mean decline in hemoglobin level was 3.06 g/dL for a mean preoperative value of 11.28 g/dL and a mean postoperative value of 8.22 g/dL. The mean preoperative hematocrit was 32% and postoperatively it was 24%, resulting in a decline in hematocrit level of 8%, as shown in Table 2.

In 34 patients, the SpO2 dropped below 90% and in 7 patients, the saturation dropped under 80%, with a lowest value of 70%. Most saturation drops took place during induction or awakening (n = 28). One of these drops lasted 30 minutes. The other 27 drops lasted shorter than 5 minutes. In 12 patients, a saturation drop occurred during surgery, each lasted less than 5 minutes. Reasons for these saturation drops were not reported. In 1 patient with high airway obstruction after extubation, a saturation drop to 70% occurred. The airway obstruction was rapidly relieved by positive airway pressure.

In 62 patients, the etCO2 stayed between 30 and 50 mm Hg. In 40 patients, etCO2 stayed below 30 mm Hg and in 1 patient, it raised above 50 to a maximum of 60 mm Hg. Total time that the etCO2 was above 50 mm Hg was 20 minutes. In 18 patients, etCO2 crossed both the lower limit of 30 mm Hg and the upper limit of 50 mm Hg. However, these deviations were short living and small. In 1 patient, etCO2 raised above 50 to a maximum of 60 mm Hg. An acute strong decrease in etCO2, in combination with sudden drop in systolic blood pressure or oxygen desaturation, possibly indicating air embolism, did not occur.

Fentanyl was used for intraoperative opioid analgesia in 111 patients with a mean dose of 4.6 µg/kg. Pethidine was used in 5 patients and sufentanil in another 5 patients.

Postoperative in hospital hyperthermia occurred 16 times (13.2%). Two patients had a temperature of above 39 degrees Celsius. In 10 cases, no focus for the hyperthermia was reported; in 4 patients, the hyperthermia was based on an upper airway infection and the other 2 patients had diarrhea. One wound-infection, without hyperthermia, occurred.

Mean length of hospital stay was 2.6 days (SD = 1). Abnormal postoperative cardiovascular parameters consisting of heart rate and blood pressure occurred in 8 patients. Bradycardia, not lower than 68 bpm, occurred in 2 patients. Two patients developed tachycardia (heart rate >160 bpm): one after transfusion and one while suffering from hyperthermia. Postoperative pulmonary aberrant values were relatively rare: 9 patients had a low respiratory rate, although not lower than 25 breaths per minute. Tachypnea (respiration rate >40 breaths per minute) occurred in 4 patients of which 2 were suffering from hyperthermia. No postoperative saturation drops occurred.

All patients received paracetamol postoperatively. Exact data on continuous morphine infusion rates were recorded in 16 patients. Earlier data on postoperative morphine administration were lost due to the change in the patient information system. In these 16 patients, morphine was infused at low speed (mean of 4.5 µg/kg/h) for a maximum of 48 hours.

No postoperative neurological complications were reported and no mortality occurred.

4 | DISCUSSION

Endoscopic strip craniectomy has been the standard of care for patients under 6 months of age in our center. Literature has shown
Open cranial vault reconstruction procedures are major surgical procedures that last about 4-6 hours with high transfusion rates and a length of hospital stay between 3 and 5 days. Duration of surgery and duration of anesthesia in this study were relatively short compared to open surgical procedures. A lesser duration of surgery and a flawless anesthesia induction and awakening is not only cost-effective but may also be safer for the patient, since average neurodevelopment scores were lower among children at the age of 6 months treated for single-suture craniosynostosis who experienced longer surgical duration and higher exposures to inhaled anesthesia. In earlier research, dural tear was the most common intraoperative surgical complication; since this had little influence on the duration of anesthesia, this parameter was not included in this research. The relationship between timing of craniosynostosis treatment, type of surgery, duration of surgery, and anesthetic exposure is currently not clearly defined; therefore more research is needed in order to draw founded conclusions regarding neurodevelopment.

The first choice of endotracheal intubation was via the oral route. However in 23 cases, endotracheal intubation via the nasal route was performed. Most of the nasal intubations were performed in patients operated in the sphinx position. In this position, endotracheal intubation via the nasal route was performed. Most of the SpO2 drops in this study occurred during induction or awakening. During these phases of anesthesia, the young patients are often agitated which leads to artifacts in SpO2 measurement or disconnection of the transducer. This could have led to an overestimation of saturation drops in this study.

The mean blood loss of 35.4 mL (5.7 mL/kg) was slightly higher than is reported for endoscopic craniosynostosis surgery in literature and so is our blood transfusion rate. The measured blood loss should be considered as an estimated blood loss, since the precise amount of blood loss is hard to determine. Although the amount of blood loss was correlated with higher transfusion rates, it is questionable if all transfusions given were the direct result of blood loss. Infection can have a significant effect on transfusion rate. In this study, only 1 patient with postoperative infection was transfused (20%). However, numbers are too little to prove causality. Since only 1 transfusion was given intraoperatively, we think that we had to deal with a significant part of patients that were transfused due to hemodilution. Our assumption of hemodilution is based on the fact that our transfusion rate dropped to 7.7% after the introduction of a revised protocol for i.v. fluids postoperatively in September 2012. From September 2012 until December 2016, 26 patients were treated with endoscopic strip craniectomy and in only 2 patients, blood transfusion was performed. Beside this, the surgical learning curve could also contribute to this decline. Erb et al stated that excessive blood loss is more common in scaphocephalic patients due to the emissary veins from the sagittal sinus and in trigonocephaly due to the thickness of the frontal bone. Furthermore, they state that patients with a body weight less than 5 kg have a higher risk for blood transfusion, but in this study there was no relevant difference in body weight between the transfused and nontransfused group, respectively 6.1 kg and 6.3 kg. Nevertheless, patients need to have good venous access intra- and postoperatively and crossed blood products need to be determined preoperatively. Another risk in patients that received PRBC is the risk of metabolic disturbances, especially the incidence of hypocalcemia and hyperkalemia, since potassium levels rise in stored PRBC. However, in this study no metabolic disturbances were measured which is probably due to our strict PRBC storage protocol. The maximum days of storage for a PRBC that are transfused to pediatric patients is 16 days, but the mean number of storage days at the time of transfusion was only 5 days. This means that potassium levels are relatively low in these PRBCs. Van Uitert et al stated that the best time to do surgery, in order to reduce blood transfusion rate, is after 6 months, after the nadir of hemoglobin, but before the bone deformity gets too extensive because of skull growth and continuing ossification of the dura after birth.

| Diagnosis         | Duration anesthesia (min) | Intraoperative crystalloids (mL/kg) | Decline in Hb (g/dL) | Decline in Hct (%) | Blood loss (mL/kg) | Transfusions (n) |
|-------------------|---------------------------|-------------------------------------|----------------------|-------------------|-------------------|-----------------|
| Scaphocephaly     | 138 (36)                  | 14 (9)                              | 2.71 (1.14)          | 9 (4)             | 5.2 (5)           | 18 (28%)        |
| Trigonocephaly    | 118 (15)                  | 14 (7)                              | 2.8 (1.22)           | 8 (3)             | 6.1 (3)           | 6 (17%)         |
| Plagiocephaly     | 113 (15)                  | 14 (11)                             | 3.01 (2.48)          | 6 (3)             | 5.0 (4)           | 0               |
| Brachycephaly     | 216                       | 25                                  | 2.58                 | 8                 | 1.4              | 0               |
| Syndromal         | 159 (35)                  | 18 (14)                             | 3.13 (1.31)          | 9 (3)             | 12 (6)            | 1 (20%)         |
| Multisutural      | 147 (23)                  | 11 (5)                              | 1.8                  | 8                 | 3 (0.7)           | 1 (33%)         |
| Total             | 131 (32)                  | 14 (9)                              | 3.06 (1.34)          | 8 (3)             | 5.7 (4)           | 26 (22%)        |

This also applies to the brachiocephalic patient since this patient needed to be repositioned during surgery.

Most of the SpO2 drops in this study occurred during induction or awakening. During these phases of anesthesia, the young patients are often agitated which leads to artifacts in SpO2 measurement or disconnection of the transducer. This could have led to an overestimation of saturation drops in this study.

The mean blood loss of 35.4 mL (5.7 mL/kg) was slightly higher than is reported for endoscopic craniosynostosis surgery in literature and so is our blood transfusion rate. The measured blood loss should be considered as an estimated blood loss, since the precise amount of blood loss is hard to determine. Although the amount of blood loss was correlated with higher transfusion rates, it is questionable if all transfusions given were the direct result of blood loss. Infection can have a significant effect on transfusion rate. In this study, only 1 patient with postoperative infection was transfused (20%). However, numbers are too little to prove causality. Since only 1 transfusion was given intraoperatively, we think that we had to deal with a significant part of patients that were transfused due to hemodilution. Our assumption of hemodilution is based on the fact that our transfusion rate dropped to 7.7% after the introduction of a revised protocol for i.v. fluids postoperatively in September 2012. From September 2012 until December 2016, 26 patients were treated with endoscopic strip craniectomy and in only 2 patients, blood transfusion was performed. Beside this, the surgical learning curve could also contribute to this decline. Erb et al stated that excessive blood loss is more common in scaphocephalic patients due to the emissary veins from the sagittal sinus and in trigonocephaly due to the thickness of the frontal bone. Furthermore, they state that patients with a body weight less than 5 kg have a higher risk for blood transfusion, but in this study there was no relevant difference in body weight between the transfused and nontransfused group, respectively 6.1 kg and 6.3 kg. Nevertheless, patients need to have good venous access intra- and postoperatively and crossed blood products need to be determined preoperatively. Another risk in patients that received PRBC is the risk of metabolic disturbances, especially the incidence of hypocalcemia and hyperkalemia, since potassium levels rise in stored PRBC. However, in this study no metabolic disturbances were measured which is probably due to our strict PRBC storage protocol. The maximum days of storage for a PRBC that are transfused to pediatric patients is 16 days, but the mean number of storage days at the time of transfusion was only 5 days. This means that potassium levels are relatively low in these PRBCs. Van Uitert et al stated that the best time to do surgery, in order to reduce blood transfusion rate, is after 6 months, after the nadir of hemoglobin, but before the bone deformity gets too extensive because of skull growth and continuing ossification of the dura after birth.
Venous air embolism is not uncommon in pediatric patients during neurosurgical procedures due to 2 reasons: the surgical site is above the heart and the presence of noncollapsible veins.\textsuperscript{4,10} In craniosynostosis surgery, the incidence of VAE during open reconstructive craniosynostosis surgery described in literature shows high variability while literature on air embolism in endoscopic craniosynostosis surgery reports a low incidence of VAE.\textsuperscript{14,19,20} In this study, no VAE occurred based on clinical condition and etCO\textsubscript{2}, possibly since only a few veins are opened due to the minimally invasive character of the procedure. This makes it less likely that air can enter the venous circulation. However, in this study precordial Doppler monitoring, which is considered as the most sensitive technique to detect intraoperative venous air embolism, was not performed.\textsuperscript{21} So we were not able to detect smaller VAE’s (Grade I) according to the scale designed by Faberowski et al.\textsuperscript{19} This could have led to an underreporting of VAEs.

Only our first 4 patients (n = 4) were admitted to the ICU for 2 days after surgery. Not because of surgical or anesthesia-related complications, but by the prudence taken by the craniofacial team regarding the new technique. After the first 4 patients, none of the patients were admitted to the ICU after surgery, but were taken to the pediatric general ward after an 1 hour stay at the postoperative anesthesia care unit.

None of the postoperative disturbances led to relevant consequences. Mean length of hospital stay was 2.6 days (SD = 1). However, as published in our recent study, there is a learning curve and currently patients stay in our center for only 24 hours postoperatively.\textsuperscript{3}

Postoperative pain management was performed according to our protocol. This means that every patient received paracetamol and could receive continuous morphine infusion when needed. It was observed that postoperative morphine could be stopped shortly after surgery based on clinical assessment. This suggests that postoperative pain was little and that pain management was adequate. However, more data need to be obtained before drawing conclusions on postoperative need for morphine administration.

5 | LIMITATIONS

Due to the retrospective character, underreporting of complications might have occurred for at least 3 factors. The first reason is that due to the retrospective study design, reporting and recording data were less accurate. Second, we possibly did not define the complications precisely enough. Third, partly due to the second reason given, the surgeon or anesthesiologist could possibly not recognize or report a complication since they did not consider the event as a complication. The retrospective nature of the study may have caused inaccuracies of estimating blood loss and may have contributed to the lack of accounting for the changes in practice over time. Furthermore, there is an inherent difficulty in estimating small volume surgical blood loss in babies, which results in a higher margin of error. Another drawback in estimation of blood loss is the difficulty in accounting for blood loss concealed on surgical drapes. Solving these lacks in methods and defining their effects on complications is the first step in continuing our study in a prospective design. For example, by combining the directly measured blood loss with a calculation based on a formula.\textsuperscript{22,23} The main missing values were preoperative hemoglobin and hematocrit levels (n = 15), intraoperative fluid administration (n = 12), and postoperative morphine administration (n = 105). Most data were missing due to different intra- and postoperative patient recording systems and the implementation of a new recording system during the study. Besides the missing data, we had to deal with different types of postoperative records, ie, most of the time it was reported that the vital parameters were within the normal range without reporting the exact values. In these cases, the patient was assigned to the normal value group.

Besides, this study is only an evaluation of our first 121 endoscopic strip craniectomy patients and does not compare endoscopic strip craniectomy to open reconstruction procedures, which means that no hard conclusions can be drawn about any (dis-)advantages regarding these techniques.

6 | CONCLUSIONS

This report is a retrospective single center’s experience including 121 endoscopic strip craniectomy cases over a 9-year period. These patients had a relatively short intraoperative course with stable vital parameters during surgery. We report a low incidence of significant venous air embolism, a blood transfusion rate of 21%, and only minor perioperative disturbances in vital parameters. In order to determine safety of endoscopic strip craniectomy, more data from large prospective trials are required.

CONFLICT OF INTEREST

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. This study about the anesthesiological course is part of a bigger research project and contains some data from earlier published research regarding the surgical technique, since these data are essential for evaluating our anesthesiological course (blood loss, transfusion rate, and postoperative infection). Publishing all data in one paper would result in a manuscript too extensive and heterogeneous for either an anesthesiological or surgical journal.

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