DOI: 10.5350/SEMB.20170417125950

The Relation Between Blood Transfusion and Arterial Blood Gas Values in Craniosynostosis Surgery: A Retrospective Study with 23 Cases

Sibel Oba[1], Canan Tulay Isil[1], Hacer Sebnem Turk[1], Pinar Sayin[1], Ferda Aybey[1], Inci Paksoy[1], Osman Turkmenoglu[2], Adem Yilmaz[2]

ABSTRACT:

The relation between blood transfusion and arterial blood gas values in craniosynostosis surgery: a retrospective study with 23 cases

Objective: Craniosynostosis surgery in infants may require increased blood transfusions, leading to arterial blood gas variations. In this study, we aimed to evaluate the relation between blood transfusion and arterial blood gas changes in infants during craniosynostosis surgery.

Material and Methods: Data of all children, who were operated in our neurosurgery clinic during a five-year period were screened retrospectively. Demographics, arterial blood gas sample results, transfusion requirements in children who underwent craniosynostosis surgery were recorded.

Results: The mean age of 23 cases was 19.00±16.26 months, 73.9% of the patients underwent single/multiple suture correction, and the mean duration of operation was 154.13±17.49 minutes. The mean transfused materials were 152.63±61.18 mL erythrocyte suspension and 125.00±57.74 mL fresh frozen plasma. At the end of the surgery, HCO3 was higher, base deficit was decreased and ionized calcium was higher compared to beginning and perioperative values. Preoperative and postoperative hemoglobin values (10.20±1.06 / 9.91±2.42) showed no difference (p=0.583).

Conclusions: Our data from this retrospective study has confirmed, that in children undergoing craniosynostosis surgery, perioperative and postoperative stable condition is related to adequate blood replacement compatible with arterial blood gas changes.

Keywords: Arterial blood gas, blood transfusion, craniosynostosis surgery

ÖZET:

Kraniosinostoz cerrahisinde kan transfüzyonu ve arteriel kan gazı değerleri arasındaki ilişki: Yirmi üç vakalık Retrospektif bir çalışma

Amaç: Çocuklarda kraniosinostoz cerrahisi, arteriel kan gazı değişikliklerine bağlı olarak artan miktarda kan tranfüzyonu gerektirir. Bu çalışmada çocuklarda kraniosinostoz cerrahisinde arteriel kan gazı değişiklikleriyle kan transfüzyonu arasındaki ilişkiyi incelemeyi amaçladık.

Gereç ve Yöntem: Beyin cerrahisi kliniğimizde beş yıl içinde ameliyat edilmiş çocukların verileri retrospektif olarak değerlendirildi. Kraniosinostoz cerrahisi geçirmiş çocukların demografik değerleri, arteriel kan gazı örneklerinin sonuçları, transfüzyon durumları kaydedildi.

Bulgular: 23 olgunun yaş ortalaması 19.00±16.26 ay, olguların %73.9'u tek ya da multipl sütürlü düzeltme operasyonu geçirmiş, operasyon süresi 154.13±17.49 dakika idi. 152.63±61.18 mL eritrosit süpansiyonu ve 125.00±57.74 mL taze donmuş plazma transfüzyonu yapılmıştı. Başlangıç ve perioperatif değelerle karşılaştırıldığında, cerrahi sonu HCO3 değeri yükselmiş, baz defisit azalmış, ionize kalsiyum yükselmişti. Preoperatif ve postoperatif hemoglobin değerleri (10.20±1.06/9.91±2.42) değişiklik göstermedi (p=0.583).

Sonuç: Bu retrospektif çalışmadaki veriler, kraniosinostoz cerrahisi geçiren çocuklarda perioperatif ve postoperatif stabil şartların arteriel kan gazı değişiklikleri ile uyumlu kan replasmanına bağlı olduğunu göstermiştir.

Anahtar kelimeler: Arteriel kan gazı, kan transfüzyonu, kraniyosinositoz cerrahisi

Ş.E.E.A.H. Tıp Bülteni 2017;51(3):212-7

[1]Sisli Hamidiye Etfal Research and Training Hospital, Department of Anesthesia and Reanimation, Istanbul - Turkey
[2]Sisli Hamidiye Etfal Research and Training Hospital, Department of Brain Surgery, Istanbul - Turkey

Address reprint requests to / Yazışma Adresi:
Canan Tulay Isil,
Sisli Hamidiye Etfal Research and Training Hospital, Department of Anesthesia and Reanimation, Istanbul - Turkey

E-mail / E-posta:
canannonaldi@yahoo.com

Date of receipt / Geliş tarihi:
March 7, 2017 / 7 Mart 2017

Date of acceptance / Kabul tarihi:
April 17, 2017 / 17 Nisan 2017

INTRODUCTION

Craniosynostosis is a condition in which one or more of the fibrous sutures in an infant skull prematurely fuses by ossification, thereby changing the growth pattern of the skull (1). It is the reason for one of the major surgeries concerning the pediatric population. Unfortunately, blood loss and hence blood transfusion requirements may be unavoidable in this type of surgery (2). Because of the small blood volume especially in infants, who are susceptible to metabolic changes even in minimal blood loss, the anesthesiologist should be aware of possible complications as hyper-hypocarbia, hypocalcemia, electrolyte derangement and metabolic acidosis (3).

It was previously reported, that metabolic disturbance during major elective craniofacial procedures in pediatrics is related to the intraoperative amount of blood loss and replacement rather than duration of surgery. It was also underlined that base deficit, which is a useful marker of physiological derangement, can remain significantly high for several hours in the postoperative period (4).

In this study, we evaluated the data of pediatric patients, who underwent neurosurgery because of craniosynostosis, which is one of the most critical operations in pediatric neuroanesthesia, and the blood transfusion requirements and changes in perioperative blood gas values.

MATERIALS AND METHODS

Records of all pediatric patients, who were operated in the Department of Neurosurgery in Sisli Hamidiye Etfal Training and Research Hospital during a five-year period (2008-2013) because of craniosynostosis, were studied retrospectively after approval of local ethics committee (310/25.03.2014). Demographical data, arterial blood gas sample results, transfusion requirements and duration of operation were recorded.

Perioperative Anesthetic Management

None of the study subjects received premedication. Intravenous access was provided via sevoflurane induction, in case of difficulty of placing an intravenous catheter. Standard general anesthesia induction was done with propofol 2 mg.kg^{-1} + fentanyl 1 μg.kg^{-1} + rocuronium 0.5 mg.kg^{-1} and anesthesia maintenance was provided with sevoflurane 2% in medical air 50%: oxygen 50% and rocuronium 0.2 mg.kg^{-1} + fentanyl 1 μg.kg^{-1} when required. Monitoring included electrocardiography, non-invasive blood pressure measuring, pulse oximeter (SPO_2), body temperature, end-tidal carbon dioxide and invasive arterial line. A central venous catheter was placed if a second larger intravenous access could not be inserted. Besides a urinary catheter was inserted to monitor urine output.

After orotracheal intubation all patients were ventilated in the Pressure-Controlled Ventilation Mode based on the basic knowledge as described in Appendix 1 (5). Inspiratory pressure value was set to maintain a tidal volume of 6-8 mL.kg^{-1}. Respiratory rate was adjusted, when required to keep end tidal carbon dioxide value between 29-37 mmHg.

Fluid requirements were calculated following the 4:2:1 rule and preoperative fluid deficits were determined by adding the fasting period and 6 ml/kg/h for third-space loss. The calculated amounts were replaced with Dextrose 5% in 0.45% Sodium Chloride by an infusion pump.

The amount of blood loss was estimated not only

Appendix-1: Age-related changes in vital signs[1]

			Arterial Blood Pressure	
Age	**Respiratory Rate**	**Heart Rate**	**Systolic**	**Diastolic**
Neonate	40	140	65	40
12 months	30	120	95	65
3 years	25	100	100	70
12 years	20	80	110	60

[1]Values are mean averages derived from numerous sources. Normal ranges may include measurements that deviate from these as much as 25-50%

by recording blood volume in the aspirator and in the gauzes but also by communication with the surgeon. Blood loss was replaced with 1 unite of red blood cells (RBC):1 unite of fresh frozen plasma (FFP); no crystalloid was used.

Arterial blood gas mesurements were performed immediately after placement of intra-arterial cannulation, at the end of calvarial remodeling (at this point excessive blood loss is expected) and at the end of surgery.

Statistical analyzes were made with NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) program. Analysis, descriptive statistics (mean, standard deviation) were performed with the Friedman's test, subgroup comparisons were performed with Dunn's multi-comparison test and relation between the variables was evaluated with Pearson's correlation test. $p<0.05$ was considered statistically significant.

RESULTS

Twenty-six patients underwent craniosynostosis surgery between the years 2008 and 2013. Because of missing records, only 23 patients' datas were included in this study.

Demographical data was shown in Table-1. Mean age was 19.00±16.26 months, youngest being 4 and oldest 55 months old; 56.5% (n=13) of the patients were boys, and the mean weight was 10.74±5.79 kg. Of the patients, 86.9% (n=20) were in American Society of Anesthesia (ASA) physical status I.

Table-1: Demographical Data (n=23)

Age (Months) Mean±SD	19.00±16.26
Weight (kg) Mean±SD	10.74±5.79
Gender Boys/Girls n (%)	13/10 (56.5/43.5)
ASA physical status n (%)	
I	20 (86.9)
II	3 (13.1)

Heart Rate (HR), mean arterial blood pressure (MABP) values were analyzed immediately after placement of intraarterial cannulation, at the end of calvarial remodeling and at the end of surgery and no statistically significant difference was found between the values (Table-2).

SPO_2 was 98-100%, axillary core temperature was 36.6-37.0°C, end tidal CO_2 was 30-40 mmHg. Surgical corrections were as follows: single/multiple-suture 73.9%, fronto-orbital remodeling 8.6% and both 17.5%. Operation duration was 154.13±17.49 minutes. Transfused were 152.63±61.18 mL red blood cells (RBC), 125.00±57.74 mL fresh frozen plasma (FFP), no platelets were transfused. Fluid requirements were given as 323.39±160.64 mL Dextrose 5% in 0.45% Sodium Chloride (Table-3).

Arterial blood gas sampling was made at the beginning of surgery, perioperatively and at the end of surgery, totally three times. The three values of pH and pCO_2 did not show statistically meaningful difference; pO_2 values were statistically meaningful different, but not clinically meaningful different;

Table-3: Operative Data and Total Blood Transfusion

Surgical correction	
Single/multiple suture n (%)	17 (73.9)
Fronto-orbital remodeling n (%)	2 (8.6)
Both n (%)	4 (17.5)
Operation Duration (minutes) Mean±SD	154.13±17.49
RBC (mL) Mean±SD	152.63±61.18
FFP (mL) Mean±SD	125.00±57.74
Fluid (mL) Mean±SD	323.39±160.64

RBC: Red blood cell, FFP: Fresh frozen plasma

Table-2: Perioperative Hemodynamical Data Synchronously to Arterial Blood Gas Analyzes

Friedman Test	Operation Beginning	Perioperatively	Operation End	p
Heart Rate	119.35±2.36	121.30±2.40	118.26±2.48	0.501
Mean Arterial Blood Pressure	50.87±1.16	50.44±0.99	51.30±1.10	0.580

Dunn's Multiple Comparison Test	Heart Rate	Mean Arterial Blood Pressure
Beginning / Perioperative	0.107	0.435
Beginning / End	0.619	0.764
Perioperative / End	0.200	0.206

Values are Mean±SD, p<0.05 is considered statistically significant

Table-4: Changes in Arterial Blood Gas Analyzes

Friedman Test	Operation Beginning	Perioperatively	Operation End	p
pH	7.35±0.08	7.37±0.06	7.38±0.05	0.501
PCO_2 (mmHg)	36.27±9.65	34.34±7.23	38.09±6.45	0.580
PO_2 (mmHg)	189.21±61.18	170.21±61.37	145.94±77.35	0.022
HCO_3 (mEq/L)	19.34±3.14	19.37±2.8	22.04±4.23	0.014
BD	-5.53±2.88	-5.21±2.73	-2.50±4.82	0.005
Ionized Calcium (mEq/L)	0.99±0.21	1.06±0.26	1.18±0.10	0.002
Dunn's Multiple Comparison Test	**PO_2**	**HCO_3**	**BE**	**İonized Ca^{++}**
Beginning / Perioperative	0.075	0.842	0.778	0.103
Beginning / End	0.010	0.042	0.028	0.001
Perioperative / End	0.342	0.004	0.003	0.056

BD: Base deficit, values are Mean±SD, p<0.05 is considered statistically significant

Table-5: Relation Between Arterial Blood Gas Values, RBC and FFP Transfusion

Pearson's Correlation Test		RBC (mL)	FFP (mL)
pH	R	-0.153	-0.067
	p	0.618	0.844
PCO_2	r	0.019	-0.121
	p	0.951	0.722
PO_2	r	0.335	0.013
	p	0.263	0.969
HCO_3	r	0.019	-0.189
	p	0.951	0.578
BD	r	0.383	0.202
	p	0.197	0.551
Ionized Calcium	r	0.431	-0.674
	p	0.142	0.023
Hemoglobin	r	-0.571	0.601
	p	0.017	0.025

RBC: Red blood cell, FFP: Fresh frozen plasma, BD: Base deficit, p<0.05 is considered statistically significant

HCO_3 values were statistically different (p=0.014) and end of surgey HCO_3 was statistically meaningful higher than beginning of surgery and perioperatively HCO_3 (p=0.042, p=0.004); Base deficit (BD) was statistically different (p=0.005), end of surgery BD was statistically meaningful fewer compared to beginning and perioperative BD (p=0.028, p=0.003); ionized calcium was statistically different (p=0.002), end of surgery BD was statistically meaningful higher compared to beginning and perioperative BD (p=0.001) (Table-4).

Hemoglobin level was followed via hemogram. Preoperative and postoperative hemoglobin values (10.20±1.06/9.91±2.42) showed no statistically meaningful difference (p=0.583).

Values of pH, pCO_2, pO_2, HCO_3, BD and ionized calcium at the operation beginning, perioperatively and at the end of the operation were not related to RBC transfusion (p>0.05). Increased RBC amount provided decreased hemoglobin variations (r=-0.571, p=0.017). Values of pH, pCO_2, pO_2, HCO_3 and BD also were not related to FFP transfusion (p>0.05). Increased FFP amount provided decreased ioized calcium variations (r=-0.571, p=0.017). Increased FFP amount lead to increased hemoglobin variations (r=-0.601, p=0.025) (Table-5).

DISCUSSION

This study indicated that pediatrics undergoing craniosynostosis surgery develop a varying degree of arterial blood gas changes. Perioperative and postoperative stabil condition appears to be related to blood loss and replacement. It should be considered that replacement of RBC should be combined with FFP. Also ionized calcium levels deserve attention during these surgical procedures. Besides, all patients should be admitted to a neurosurgical postoperative intensive care unit for monitoring.

Sisli Hamidiye Etfal Training and Research Hospital is a complex with almost all pediatric departments, where preponderant pediatric surgery is performed. Craniosynostosis is one of the major surgeries in children aged under two years performed in the neurosurgery clinic. Surgical corrections include sagittal synostosis (extended strip craniectomies, spring-assisted cranioplasty, total calvarial remodeling), frontal orbital advancement and remodeling, posterior expansion and remodeling, midface advancement (Le Fort III and monobloc procedures) (6-9). The population of this study was mostly aged under two years and underwent single-multiple-suture 73.9%, fronto-orbital remodeling 8.6% and both 17.5%. Unfortunately data of concomittant syndromes was missing and therefore we could not determine the frequency of Muenke, Apert, Crouzon, Pfeiffer and Saethre-Chotzen syndromes, which are associated with craniosynostosis (10).

In our study all patients were monitored with electrocardiography, invasive arterial blood pressure, pulse oximeter, end-tidal and CO_2 axillary core temperature. A central venous catheter was placed if a second larger intravenous access could not be inserted, which was required in only one patient in this study group. Stricker et al. (11) demonstrated that the implementation of routine central venous pressure monitoring was not associated with decreased duration of hypotension. Also complications during placement as bradycardia, cardiac arrest or vascular injury were increased in pediatrics. Therefore they recommended noninvasive monitoring for fluid therapy guidance. We did not observe any complication during the placement of the central venous pressure catheter, but in our clinical practice we agree to Sticker et al.

Fluid was replaced with Dextrose 5% in 0.45% Sodium Chloride. Blood loss was estimated by communication with surgeon, blood volume in the aspirator and gauzes filled with bood and replaced with RBC and FFP immediately. In our study, fluid transfusion was made approximately $10 mL.kg^{-1}$. Pediatric red blood cell bags are prepared in smaller volumes as 100 mL, even 50 mL when required, and one red blood cell package is divided into three in our blood center. Every blood bag is warmed to core temperature before infusion and transfusion related complications in the early period are closely supervised. Blood consumption in this study was about 150 mL of RBCs and 125 mL of FFP per patient, no platelets were transfused. Four patients in this study did neither receive a blood transfusion nor a fresh frozen plasma transfusion. Because of increased blood loss in craniosynostosis surgery, we usally use the 1:1 RBC:FFP transfusion protocol, which is recommended in massive blood transfusion (12). We think, that this transfusion protocol ensured an acceptable hemoglobin level in our study patients. But the limitation in this study was that only 23 patients were analyzed and a larger study group could give more precise results. In our study we observed that despite appropriate transfusion, arterial blood gas values of HCO_3, BD and ionized calcium varied perioperatively and showed statistically meaningful difference. However, these variations were taken under control with blood replacement, fluid transfusion and perioperative close hemodynamical follow-up. Howe et al. (13) conducted a study in Australia on 127 patients younger than 24 months, who underwent craniosynostosis surgery, and underlined that perioperative blood loss could even exceed the total blood volume of the pediatric patient. Difficulty in estimating blood loss due to the small blood volume requires right timing and proper amount of blood transfusion, which commonly depends on the clinician’s experience.

On the other hand, the anesthesiologist should be aware of common metabolic changes in infants perioperatively. First warming with heating blanket or air devices should be ensured, core temperature should be maintained near to 36°C (14). In our study core temperature was monitored axillary and kept at values near to 36.5°C, and no hypo-hyperthermia was observed (15,16). Even when blood transfusion is done in time and in proper amounts, increased blood loss results with metabolic acidosis and electrolyte disturbances, which leads to increased morbidity and mortality in the pediatric patient (17). Blood samples are directives for electrolyte imbalances and their adequate replacement. Invasive arterial monitoring simplifies this step and arterial blood gas sampling is usually a good guidance. Arterial blood gas analysis was done especially at the end of calvarial remodeling. Regarding to our clinical experience, we inserted a catheter for arterial monitoring into the radial artery and ensured close follow-up of hemodynamical changes. This study drew attention to ionized calcium, which decreased with increased FFP transfusion. In a study, hemodynamic instability caused by hypocalcemia as a result of exogenous citrate load and requirement of monitoring for adequate calcium replacement to prevent these adverse effects was underlined (18). We think that prospective clinical studies can elucidate the importance of ionized calcium.

Goyal et al. (19) reported a retrospective analysis on operated 95 craniosynostosis patients and emphasized that these patients should be admitted to an intensive care unit for postoperative recovery. Although no hemodynamical imbalance, desaturation or hypothermia were observed in our study, we suggest that all pediatric patients undergoing craniosynostosis surgery should be admitted to a postoperative intensive care unit, because it may take some time for total recovery of the metabolic changes, which can be detected with the arterial blood gas samples.

Our data from this retrospective study has confirmed that in children undergoing craniosynostosis surgery, peri-and postoperative stable condition is related to adequate blood replacement, compatible with arterial blood gas changes. Also, these groups of patients should be admitted to a neurosurgical intensive care unit postoperatively for monitoring of early transfusion-related complications.

Competing interests: There are no competing interests.

Financial competing interests: There are none, financial support was provided by the authors and departmental sources.

REFERENCES

1. *Kinsman SL, Johnston MV. Craniosynostosis. In: Kliegman RM, Behrman RE, Jenson HB, Stanton BF (eds). Nelson Textbook of Pediatrics.19th ed. Philadelphia, Pa: Saunders Elsevier 2011; 585: 12.*
2. *White N, Marcus R, Dover S, Solanki G, Nishikawa H, Millar C. Predictors of blood loss in fronto-orbital advancement and remodeling. J Craniofac Surg 2009; 20: 378-81.* **[CrossRef]**
3. *Hughes C, Thomas K, Johnson D, Das S. Anesthesia for surgery related to craniosynostosis: a review. Part 2. Paediatr Anaesth 2013; 23: 22-7.* **[CrossRef]**
4. *Choi AY, Ahmad NS, de Beer DA. Metabolic changes during major craniofacial surgery. Paediatr Anaesth 2010; 20: 851-5.* **[CrossRef]**
5. *American Academy of Pediatrics-Section on Anesthesiology. Guidelines for the pediatric anesthesia environment. Pediatrics 1999; 103: 512.* **[CrossRef]**
6. *Stricker PA, Shaw TL, Desouza DG, Hernandez SV, Bartlett SP, Friedman DF, et al. Blood loss, replacement, and associated morbidity in infants and children undergoing craniofacial surgery. Paediatr Anaesth 2010; 20: 150-9.* **[CrossRef]**
7. *Ririe DG, David LR, Glazier SS, Smith TE, Argenta LC. Surgical advancement influences perioperative care: A comparison of two surgical techniques for sagittal craniosynostosis repair. Anesth Analg 2003; 97: 699-703.* **[CrossRef]**
8. *Thomas K, Hughes C, Johnson D, Das S. Anesthesia for surgery related to craniosynostosis: a review. Part 1. Paediatr Anaesth 2012; 22: 1033-41.* **[CrossRef]**
9. *Mackenzie KA, Davis C, Yang A, MacFarlane MR. Evolution of surgery for sagittal synostosis: the role of new technologies. C J Craniofac Surg 2009; 20: 129-33.* **[CrossRef]**
10. *Cohen MM. An etiologic and nosologic overview of craniosynostosis syndromes. Birth Defects Orig Artic 1975; 11: 137-89.*
11. *Stricker PA, Lin EE, Fiadjoe JE, Sussman EM, Pruitt EY, Zhao H, et al. Evaluation of central venous pressure monitoring in children undergoing craniofacial reconstruction surgery. Anesth Analg 2013; 116: 411-9.* **[CrossRef]**
12. *Kashuk JL, Moore EE, Johnson JL, Haenel J, Wilson M, Moore JB, et al. Postinjury life threatening coagulopathy: Is 1:1 fresh frozen plasma:packed red blood cells the answer? J Trauma 2008; 65: 261-70.* **[CrossRef]**
13. *Howe PW, Cooper MG. Blood loss and replacement for paediatric cranioplasty in Australia - a prospective national audit. Anaesth Intensive Care 2012; 40: 107-13.*
14. *Torossian A. Perioperative thermal management in children. Anasthesiol Intensivmed Notfallmed Schmerzther 2013; 48: 278-80.* **[CrossRef]**
15. *Ayers J, Graves SA. Perioperative management of total parenteral nutrition, glucose containing solutions, and intraoperative glucose monitoring in paediatric patients: a survey of clinical practice. Paediatr Anaesth 2001; 11: 41-4.* **[CrossRef]**
16. *Arya VK. Basics of fluid and blood transfusion therapy in paediatric surgical patients. Indian J Anaesth 2012;56:454-62.* **[CrossRef]**
17. *Rath GP, Dash HH. Anaesthesia for neurosurgical procedures in paediatric patients. Indian J Anaesth 2012; 56: 502-10.* **[CrossRef]**
18. *Jawan B, de Villa V, Luk HN, Chen YS, Chiang YC, Wang CC, et al. Ionized calcium changes during living-donor liver transplantation in patients with and without administration of blood-bank products. Transpl Int 2003; 16: 510-4.* **[CrossRef]**
19. *Goyal K, Chaturvedi A, Prabhakar H. Factors affecting the outcome of patients undergoing corrective surgery for craniosynostosis: A retrospective analysis of 95 cases. Neurol India 2011; 59: 823-8.* **[CrossRef]**