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Original Article

Repair of craniosynostosis: A study of blood loss and transfusion practice

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Abstract

The anticipated problems during craniosynostosis repair include difficult airway, substantial blood loss, temperature regulation, position of the patient, venous air embolism, lengthy procedure and electrolyte imbalance. In an attempt to evaluate the blood loss and adequacy of transfusion practice we conducted the present study. The computerised database and medical records of 20 patients who underwent repair of craniosynostosis under general anaesthesia with full monitoring were studied. The age and body weight mean values were 21.6 months and 9.95 kg respectively. The duration of surgery mean value was 7.5 hr (range: 5-11 hr). The estimated blood loss was 1061 ml and 754 ml among the syndromic and non-syndromic patients respectively with significant difference ($P<0.05$). The overall estimated blood loss mean value was 892.5 ml (range: 200-3000 ml). That value varied from 0.6-2.08 times the estimated blood volume. Transfusion of PRBCs was used for all patients, mean 626 ml (range: 150-3000 ml).

Crystalloids transfused to all patients with mean of 1034 ml (range: 250-2500 ml). Colloids transfused to 18 patients (90%). Positive correlation was found between the estimated blood loss and the age, weight of the patients as well as the duration of surgery ($P=0.085$, 0.033 and 0.001 respectively). We reported one intraoperative mortality in our series due to massive air embolism and excessive bleeding. Also, we reported one case of intraoperative pulmonary oedema, in a patient without CVP line inserted, due to fluids overload treated successfully with frusemide with no further sequelae. In conclusion, blood loss during surgical repair of craniosynostosis remains difficult to estimate. Close observation of the surgical field and communication with the surgeon should be maintained. We believe that rough estimation of the blood loss during our series was enough determinant of the adequacy of blood transfusion. Further studies are needed on the long term effects of massive blood transfusion. *(p33-39)*

Keywords: *Craniosynostosis, surgery, massive blood transfusion and anaesthesia*

Introduction

Craniosynostosis is a congenital defect leading to premature closure of one or more of the cranial sutures. The reported incidence of craniosynostosis is 1 per 2000 live births.[2] The disease is classified into either non-syndromic, which involves single cranial suture or syndromic craniosynostosis, which is associated with other congenital defects and involves multiple cranial sutures eg. Aperts's syndrome, Crouzon's syndrome and Carpenter syndrome.[8] Early surgical intervention was recommended in the majority of cases to avoid serious increase of the intracranial pressure (ICP). However, the relationship between ICP and cranial suture fusion is complex and poorly understood. The aim of surgery is to correct the deformity at earlier age to prevent any cerebral consequences. Usually surgical correction is performed in young infants with a small blood volume and represents major surgery with extensive blood loss.[4] Anaesthesia for repair of craniosynostosis represents a challenge to the anaesthetists due to the anticipated problems such as difficult airway, substantial blood loss, temperature regulation, position of the patient, venous air embolism, lengthy procedure and electrolyte imbalance.[8] Therefore, we conducted the present study in an attempt to determine the anticipated problems and to evaluate the blood loss and adequacy of transfusion practices in view of massive transfusion and the difficulty to measure the intraoperative blood loss accurately.

Patients and methods

The computerised database (in the Department of Neurosurgery) and the medical records of 20 patients with craniosynostosis who underwent surgical repair between February 1995 and May 2000 at King Khalid University Hospital, Riyadh, Saudi Arabia, were reviewed. The data entry were made on a prospective case-by-case basis and all variables included in this study were present in the database. The variables collected for each patient

Table 1 - Intraoperative physiological variables (mean ±sd)

Variables	1st Hour	2nd Hour	3rd Hour	4th Hour	5th Hour	6th Hour	7th Hour
MAP	61.5(10.5)	64.7 (9.8)	63.6 (15.5)	68 (12)	71 (14)	66.5 (8.4)	-
CVP	7 (3)	7 (3)	8 (2)	9 (2)	8 (3)	8 (3)	-
H.R	125 (19)	122 (19)	113 (25)	110 (30)	114 (34)	95 (7)	-
TEMP	36.5 (7)	36.3 (0.8)	36.2 (0.7)	36.3 (7)	36.1 (1)	36.4 (1.2)	-
Hb	10.5 (1.5)	11.1 (2.6)	12.4 (2.1)	12.7 (2.2)	12.9 (2.9)	13 (4.3)	13.3 (0.5)
PaO2	197 (64)	195 (61)	197 (55)	198 (64)	190 (51)	197 (48)	205 (59)
PaCO2	30 (4)	34 (4)	33 (4)	35 (5)	36 (3.8)	35.5 (3.4)	32.5 (1.9)
HCO3	20.8 (1.9)	20.8 (2)	19 (2)	19.8 (1.9)	20.8 (2.4)	20.8 (2.8)	-
BE	3.3 (1.4)	4 (1.7)	5.2 (2.2)	5.7 (2)	4 (2.6)	-	-
K+	3.2 (2.8)	3.5 (0.4)	3.6 (0.5)	3.7 (0.5)	3.6 (0.5)	3.7 (0.3)	3.6 (0.4)
O2 sat %	98.8 (2)	99 (0.2)	99 (0.3)	98.8 (1.1)	98.8 (1.1)	99.1 (0.5)	-
SpO2	98.8 (1.6)	97.5 (2.5)	98 (1.7)	98.2 (1.7)	98.6 (0.9)	98.2 (1.3)	-
Etco2	33 (4)	30 (4)	29 (5)	29 (3.6)	29 (3.7)	29.4 (4.4)	-

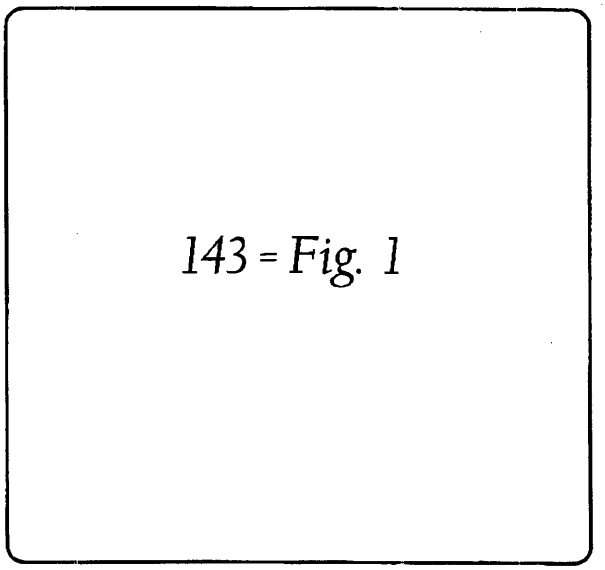

Figure 1 - Correlation between the age of the patients (mo) and the blood loss (L), P=0.085

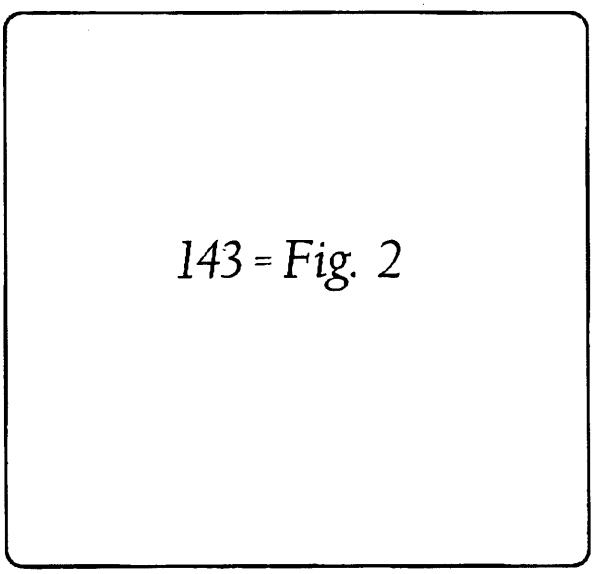

Figure 2 - Correlation between the weight of the patients (kg) and the blood loss (L), P= 0.33

included: age, sex, body weight (b.w), preoperative diagnosis, airway assessment, ASA status, preoperative laboratory results, estimated blood loss, intravenous transfusions of fluids and blood, duration of surgery, physiological parameters, length of stay in the paediatric intensive care unit (PICU) and overall outcome. Patients were evaluated preoperatively for difficult intubation and status of peripheral veins. Premedication consisted of atropine 20 micrograms/kg i.m for patients less than 1 year and trimeprazine syrup 2-3 mg/kg orally for older patients.

Four units packed red blood cells (PRBCs), 4 units fresh frozen plasma (FFP) and 4 units of platelets were prepared. The operating room was warmed up and a mandatory check of anaesthesia machine, circuits, monitors, airway equipment and drugs prior to the child's arrival to the operating room were undertaken. All operations were performed by the same surgeon. Anaesthesia was managed according to the preference of each attending anaesthetist. After placement of the largest possible size of i.v cannula, induction of anaesthesia was achieved for all patients with 2 MAC sevoflurane in 50% nitrous oxide in oxygen. Endotracheal intubation was facilitated by i.v atracurium 0.5mg/kg b.w. Throat pack was used for all patients following correct placement of the esophageal stethoscope. Right internal jugular vein and either femoral or radial arteries were cannulated except for one patient who had no central venous line inserted. Anaesthesia was maintained with 0.5-1 MAC sevoflurane in 50% nitrous oxide in oxygen with i.v infusion of fentanyl (0.5 ug/kg/hr) and atracurium (0.3mg/kg/hr). Monitoring included continuous ECG, core temperature, non-invasive and invasive arterial blood pressure, central venous pressure (CVP), regional tissue oxygen saturation (SpO2), end-tidal carbon dioxide (ETCO2) and urine output. Patients were wrapped in cling film to reduce intraoperative heat loss and placed in a supine position with 20-25° head-up tilt. The surgeon infiltrated the scalp with a mixture of lignocaine and adrenaline (1:200,000) solution. The surgical procedure performed through a bicoronal zigzag incision and subperiosteal dissection down to the orbital rims. Followed by bifronto-

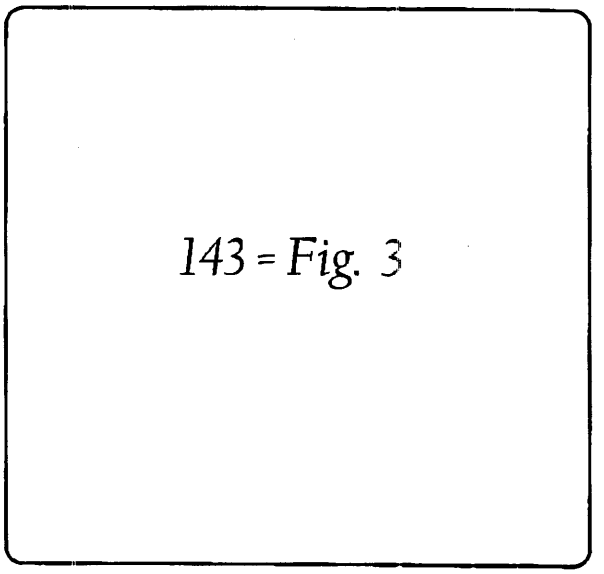

Figure 3 - Correlation between the duration of surgery (hr) and the blood loss (L), P=0.001

parietal craniotomy using high speed air craniotome. Then an orbital roof osteotomy was made through the lateral orbital wall below the level of the frontozygomatic suture.

After remodeling the frontal-parietal bone to the desired position, fixation is done using absorbable sutures, wires and microplates according to the patient's age and bone thickness. Then the supra-orbital bone was advanced by 1.5-2 cm. The intra-operative physiological parameters were recorded continuously every 5 minutes.

Arterial blood gases and blood glucose were monitored every 60 minutes. Input and output charts were regularly monitored. Blood loss was estimated by the volume of blood in the suction canister, visual and weighing of sponges. Transfusion of fluids, blood and blood by-products were guided by the CVP trend, mean arterial blood pressure, acid base status and urine output rather than the absolute values. At the end of surgery the patients were assessed for extubation, otherwise they were sent to the PICU with the trachea intubated and the lungs ventilated for further management. All the data were subjected to two-way ANOVA for continuous outcomes (SAS, PROC, SAS Institute, North Carolina) and student's-t-test was used for comparative analysis where $P<0.05$ was considered significant. The blood volume was estimated as 85 ml/kg b.w for patients < 10 kg and 80 ml/kg b.w for patients >10kg. Correlation between the blood loss and the patient's age, body weight and duration of surgery were also obtained.

Results

In a 4-year period, we studied 20 patients who underwent operative craniosynostosis. Patients were of both sexes (9 males). The mean age in months (mo) at operation was 21.6 (range: 6-84 mo). Ten patients (50%) were less than 12 mo old. The mean b.w was 9.95 kg (range: 4-16 kg). Fourteen patients were less than 10kg b.w. Nine patients were syndromic craniosynostosis (45%), one patient with Pfeiffer's syndrome, one patient with Carpenter syndrome, five patients with Apert's syndrome and two patients with Crouzon syndrome. Invasive monitoring was used in all patients except one patient who had no CVP line inserted. The mean duration of surgery was 7.5 hr (range: 5-11 hr). The mean values of estimated blood loss among the syndromic and the non-syndromic patients were 1061 ml (range: 200-3000 ml) and 754 ml (range: 300-1500 ml) respectively. Comparing the mean values revealed significant high value of the estimated blood loss among the syndromic versus the non-syndromic patients ($P<0.05$). The overall mean value of the estimated blood volume was 822 ml (range: 340-1440 ml). The mean value of the estimated intraoperative blood loss was 892.5 ml (range: 200-3000 ml). The estimated blood loss varied from 0.6-2.08 times the estimated blood volume. All the children had intraoperative transfusion with a mean of 626 ml (range: 150-3000 ml) of PRBCs. Fresh frozen plasma was used in only 5 patients (25%) with a mean of 124 ml (range: 100-170 ml). Platelets transfusion was used in only 2 patients (10%) with

a mean of 120 ml (range: 40-200 ml). Crystalloids were used in all patients with a mean of 1034 ml (range: 250- 2500 ml) and colloids were used in 18 patients (90%) with a mean of 331.6 ml (range: 70-750 ml). The patient with no CVP line had pulmonary oedema due to overtransfusion and treated with i.v frusemide with no other sequelae. The intraoperative haemodynamic, arterial blood gases mean (sd) and other physiological parameters up to the 7th hour intraoperatively are shown in Table 1. In only 3 patients the trachea was extubated at the end of surgery (15%). The mean duration of stay in the PICU was 2.9 days (range: 1-7 days).

The overall operative outcome was good in 19 patients (95%) except one intraoperative mortality (5%) due to massive blood loss and air embolism detected by sharp descent of the ETCO2 reading. The age, weight of the patients and the duration of surgery correlated highly with the estimated blood loss during surgery (Fig. 1-3).

Discussion

Anaesthesia for surgical repair of craniosynostosis involves many anticipated problems. Substantial blood loss and massive blood transfusion are the two major problems encountered intraoperatively. It has been recommended that the operation be performed before 3 mo of age although in some other centres 7-12 mo was defined as an optimal window for craniofacial repair.[9] In our series, the estimated blood loss varied from 0.6-2.08 of the estimated blood volume, which is considerably higher than previously reported results.[4,7] One patient in our series received more than one blood volume packed PRBCs (5%) intraoperatively, which is in accordance with the previous incidence of 3-5% in another study.[3]

Several studies had reported positive correlation between blood loss with the patient's age, body weight, controlled ventilation in the prone position, hypotensive anaesthesia and the number or the type of cranial sutures involved.[10] That is in accordance with our series where such correlations were reported. Moreover, positive correlation was detected in our series between the duration of surgery and the estimated blood loss. Though previous studies had attempted to accurately calculate the blood loss during this procedure by using pre- and post transfusion haemoglobin or estimated red cell mass, assessment of blood loss during neurosurgery especially in craniosynostosis repair remains difficult. The blood loss in craniofacial surgery is multifactorial, however, it is recognised that a constant low grade ooze of blood from the scalp and cut bone is the predominant contributor. Such bleeding continues at a low grade despite efforts of haemostasis. As such, longer cases can be reasonably expected to have greater blood loss. Esophageal echo-Doppler device was used successfully as a non-invasive monitor to assess the aortic blood flow during repair of craniosynostosis.[11]

However, the method used in the present study is obviously a rough estimate, we ensured adequate fluid replacement based on inaccurate estimation of the blood loss by maintaining the volume status as our prime priority. Guidelines adhered to were the trend of CVP, the mean arterial pressure, acid-base status and urine output rather than the absolute values. If the CVP and the blood pressure dropped during periods of surgical intervention known to be associated with significant bleeding, it was treated aggressively with brisk transfusions. One patient in our series, with no CVP line inserted, had intraoperative pulmonary oedema due to overtransfusion, although he was adequately treated, but we believe that CVP line insertion is important in such procedures with expected massive bleeding. Though levels of haemoglobin between 7-10 gm/dl are considered to be adequate to maintain oxygen delivery in normal circumstances, acidosis and the exchange of native red cells to stored ones may affect oxygen delivering capacity. Higher level of haemoglobin should be maintained

during massive blood loss and transfusion.

Close observation of the surgical field and communication with the surgeon are important aspects in the assessment of blood loss. Periods of heavy bleeding during surgical intervention are mainly during mobilisation of the scalp flap, bifrontal craniotomy and orbital osteotomy. Prior to proceeding from one stage to another, the patient should be adequately transfused to maintain tissue perfusion and hence adequate oxygen delivery. Intraoperative dilutional coagulopathy can occur when only packed red cells are transfused in patients with massive blood loss. Massive blood transfusion carries many side effects, in one study it was shown that pre- and postoperative treatment with erythropoietin can be safely applied in the great majority of children with craniosynostosis.[1] About 40% of coagulation factors and platelets remain in the circulation after one blood volume replacement.[10] Coagulopathy secondary to massive transfusion is mainly a complication of shock, tissue hypoperfusion and acidosis due to delayed or inadequate resuscitation.[3] In one series, 13 patients out of 23 received FFP as blood loss equaled one or more than one blood volume.[4] As the decay of platelets during massive transfusion is quite unpredictable its use should be supported by evidence of low platelet count. Eleven patients in our series received platelets intraoperatively when the blood loss exceeded more than one blood volume. Although we did not monitor coagulation indices intraoperatively, its monitoring is essential. Blood products like FFP and platelets should be transfused on evidence of laboratory data.[10] Postoperative drop in the haematocrit on the first postoperative day is usually attributed to either a considerable amount of subglial accumulation of blood or it may be dilutional as the 3rd space losses are absorbed intravascularly in the initial postoperative period.[5] We reported one intraoperative mortality in our study due to massive blood loss and air embolism.

In another study one mortality out of 130 craniosynostosis patients was reported due to the same reasons.[7] Maintenance of intravascular volume not only ensures adequate tissue perfusion but also prevents venous air embolism.[6]

In conclusion, blood loss during surgery for craniosynostosis is massive. Invasive monitoring is essential in order to determine the status of the intravascular volume and accordingly the volume of blood and fluids to be replaced. Close observation of the surgical field and constant communication with the surgeon should be maintained during surgery. We believe that rough estimation of the blood loss during our series was enough determinant of the adequacy of blood transfusion.

We think that long term effects of massive blood transfusions among those cases should be further studied.

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GENTLE REMINDERS

Common causes of blood loss in the multiple trauma patient

1. Scalp lacerations
2. Maxillofacial injuries
3. Compound fractures
4. Other soft-tissue injuries
5. Intraperitoneal or retroperitoneal
6. Hemothorax
7. Pelvic haematoma
8. Bleeding into extremities at site of long-bone fractures
9. Subgaleal or extradural haematoma in an infant
10. Traumatic rupture of the aorta