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Pediatric Anesthesia

Metabolic changes during major craniofacial surgery

(Prospective Observational Study of the Metabolic Status of Children Undergoing Major Craniofacial Surgery)

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METABOLIC CHANGES DURING MAJOR CRANIOFACIAL SURGERY

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OBJECTIVES

The purpose of this study was to document the degree and duration of perioperative metabolic disturbance during major craniofacial surgery in children.

AIM

The aim was to quantify the degree and duration of perioperative metabolic disturbance and secondly to determine the relationship between the metabolic changes and the duration of surgery and total volume of blood and colloid given during surgery.

BACKGROUND

These patients have the potential for massive blood loss and significant metabolic acidosis.

Routine perioperative monitoring includes the serial measurement of base deficit as a marker of metabolic disturbance.

METHODS/MATERIALS

All patients undergoing elective major craniofacial surgery were prospectively studied over a 10-month period. Base deficit from arterial blood gas analysis was measured at standardised intervals during the perioperative period. The duration of surgery and total volume of blood and colloid given intraoperatively were used as covariates in a multiple regression analysis.

RESULTS

Maximum recorded base deficit ranged from -3 to -20 (median -9). Median time taken to return to normal was 9.25h (range 0-18h). Median duration of significant base deficit was 3.8h (range 0-20h).

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CONCLUSIONS

Children undergoing major craniofacial surgery develop a varying degree of perioperative metabolic acidosis persisting for several hours. The maximum base deficit appears to be related to the amount of intraoperative blood loss and replacement rather than duration of surgery. As it is difficult to predict the extent and duration of metabolic acidosis for an individual patient, this study confirmed our current practice that all patients should be admitted to a neurosurgical high dependency unit postoperatively for overnight monitoring.

KEYWORDS

Craniofacial surgery

Metabolic

Perioperative acidosis

INTRODUCTION

Great Ormond Street Hospital is one of several Trusts which carry out complex elective surgery for paediatric craniofacial abnormalities. Children undergoing major craniofacial surgery can be categorised according to whether they are undergoing procedures for surgical correction of single suture craniosynostosis and fronto-orbital remodelling or more extensive surgery including monobloc/fronto-facial advancement. They have the potential for massive blood loss and significant metabolic acidosis (1, 2). Routine perioperative monitoring includes base deficit analysis from serial arterial blood gas sampling. The current practice in this Trust is for this to be continued postoperatively for all patients, overnight on the high dependency unit.

The aim of the study was to quantify the degree and duration of metabolic disturbance associated with major craniofacial surgery using the current practice of clinical monitoring. In addition, the relationship between the base deficit and both duration of surgery and total volume of blood and colloid given during surgery was analysed.

Patients undergoing monobloc/fronto-facial advancement were excluded from the study on the basis that they constitute a different surgical group and their perioperative care is managed differently.

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MATERIALS AND METHODS

Local Research Ethics Committee exemption was attained on the basis that no additional interventions or changes to standard perioperative care would be instituted. All patients undergoing elective major craniofacial surgery (fronto-orbital remodelling, sagittal biplication, posterior and biparietal vault expansion, but excluding monobloc distraction/fronto-facial advancement) were prospectively studied over a 10-month period. The primary outcome measure was base deficit from arterial blood gas analysis. This was used as a marker of metabolic disturbance and measured at standardised intervals during the perioperative period. A significant base deficit was defined as being 33% of the normal range less than the lower parameter, i.e. a base excess of less than -6 (normal reference range for base excess in children is -4 to +2) (1). Duration of surgery and total volume of blood and colloid given intraoperatively were used as covariates in a multiple regression analysis.

Preoperative data were collected, including age, gender, weight, ASA grade, significant past medical history, presence of associated syndrome, time of last oral intake before surgery, and laboratory results (including preoperative haemoglobin, platelet count, urea, creatinine and electrolytes). The type and amount of fluid administered during the intraoperative period were recorded.

The primary outcome measure, base deficit, was recorded from arterial blood gas analysis using the i-STAT® Portable Clinical Analyser. This was measured at standardised time intervals, from time of insertion of arterial cannula, hourly during surgery, at application of bandages, on arrival to the recovery area, and four-hourly on the high dependency unit until the patient was discharged to the general ward area or removal of arterial vascular access.

Duration of surgery, as defined by time taken from “knife to skin” to application of bandages after completion of the surgical procedure, and the total volume of blood and colloid given intraoperatively were recorded as covariates for subsequent data analysis.

Other intra- and postoperative data which were documented included the type of surgical procedure, clinical observations at time of base deficit measurement (heart rate, mean arterial blood pressure, peripheral oxygen saturation, capillary refill time, core temperature, urine output, central venous pressure if monitored), volume and type of fluid given, and blood glucose at time of sampling.

Anaesthetic technique consisted of intravenous or gaseous induction followed by maintenance of general anaesthesia with a volatile inhalational agent.

A descriptive numerical and graphical data analysis was carried out using the Statistical Package for Social Science for Windows version 15 (SPSS Inc., Chicago, IL, USA). Multiple regression analysis was performed on the primary outcome measure to determine the relationship between the magnitude of metabolic acidosis and the covariates. In order to detect a moderate correlation (0.5) between the outcome measure and covariates, a sample size of at least 25 patients was required (power 80%, $p < 0.05$).

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RESULTS

A total of 28 patients were recruited during the study period. Out of these 28 patients, 19 (68%) analysed were male. The number of patients assessed as ASA 1 was 9 (32%), 13 (46%) as ASA 2, and 6 (21%) as ASA 3. There were four patients who were recorded as having Crouzon syndrome, two with Saethre-Chotzen, one with Apert, and one with Pfeiffer syndrome. The median age at surgery was 19m (range 4m-17y). There were 18 (64%) patients under 2 years of age at time of surgery. Weight of patients ranged from 6.2 to 54.0 kg (median 11.9). At time of surgery, 21 (75%) patients weighed 15 kg or less.

A total of 13 (46%) of the surgical procedures were classified as fronto-orbital remodelling for single suture craniosynostosis. The remaining procedures included sagittal biplication, and posterior and biparietal vault expansion. The median operative time was 3.1h (range 1.2-7.8h).

The median value for base deficit (BD) at the start of surgery was -4 (range -7 to +1) while for maximum recorded perioperative base deficit it was -9 (range -20 to -3). The capillary refill time was noted to be normal (<2s) at the time of each arterial blood sampling. The median time from commencement of surgery to maximum base deficit was 3.5h (range 0-11.5h) while the time taken to return to a normal level, defined as a $BD \geq -6$, was 9.25h (range 0-18h). The median duration of significant base deficit, as defined by a $BD < -6$, was 3.8h (range 0-20h). A median total volume of 55ml.kg^{-1} (range $10\text{-}148\text{ml.kg}^{-1}$) of blood and colloid was administered intraoperatively. Only one patient did not receive blood intraoperatively, but a blood transfusion was administered in the immediate postoperative recovery period.

Multiple regression analysis of variance (ANOVA) was used with weight as a dependent variable to allow for the size of each patient. Using maximum base deficit as the independent variable and total volume of blood and colloid given intraoperatively and duration of surgery as dependent variables, there was a statistically significant relationship between maximum base deficit and volume of fluid ($p = 0.02$, correlation coefficient = -0.835 , $r^2 = 0.466$) but no significant relationship with duration of surgery ($p = 0.58$, correlation coefficient = 0.193 , $r^2 = 0.293$).

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DISCUSSION

Craniofacial surgery is performed in children in order to correct deformities of the cranial bones, orbits and midface. This type of surgery is often performed at an early age and is associated with prolonged operating times, extensive operative exposure, and significant heat and blood loss (3, 4). Estimation of intraoperative blood loss in patients undergoing craniostomosis repair is often inaccurate and significantly underestimates actual blood loss (5, 6). Almost all patients undergoing repair of craniofacial deformities will need a blood transfusion with potential for massive blood transfusion (4). One objective of intraoperative monitoring is to guide fluid replacement improve perioperative outcome and reduce adverse events (7).

The development of a metabolic acidosis is common in patients undergoing extensive surgery involving significant blood loss (8). This may be the result of a combination of blood loss and electrolyte shifts following the administration of large amounts of crystalloid, colloid and blood products. The base deficit, an indicator of metabolic acidosis, has been shown to correlate with the severity of haemorrhagic shock in patients with multiple trauma, and can be used in quantifying the response to haemorrhage in trauma or non-trauma patients (9). Furthermore, haemodynamic and haemorrhagic complications of surgery have been shown to be associated with a low base deficit value and an increased length of stay in the intensive care unit (10). A recent study by Stricker et al shows that a significant metabolic acidosis occurs within both the intra and postoperative period during major craniofacial surgery (2). However our study describes the metabolic changes throughout the time course during the perioperative period.

This study recorded a wide variation in degree and duration of metabolic disturbance in the intra- and postoperative period. A severe metabolic derangement developed in 11 (39%) of the patients, with a measured base deficit of ≤ -10 . For five patients (18%) the duration of significant acidosis lasted for over 10 hours. In 23 patients (79%), the maximum base deficit occurred after the end of surgery with the majority (14) having a subsequent period of significant metabolic acidosis during the postoperative care in the recovery area and on the high dependency unit. One patient developed ongoing severe metabolic acidosis along with clinical deterioration and required subsequent emergency management and transfer to intensive care. Intravenous bicarbonate was given on an individual basis alongside clinical assessment. No other patients received intravenous bicarbonate. Three patients still had a significant base deficit following overnight high dependency care, but did not need a higher level of critical care. The majority of patients (86%) had a measured base deficit in the normal range following the overnight care on the high dependency unit. Arterial blood gas sampling was taken at hourly intervals intraoperatively and 4 hourly postoperatively. This limits the accuracy of our study in assessing the maximum base deficit and return to normal range.

The total volume of blood and colloid given intraoperatively was used as a surrogate measurement of blood loss. The assumption is made that all patients were maintained in a euvolaemic status at the time of each arterial blood gas measurement, as all recorded clinical observations of capillary refill time were normal (< 2 seconds) at the time of sampling. Any coagulopathic derangements were also corrected intraoperatively as guided by haematological laboratory results. There was a statistically significant relationship between maximum base deficit and total volume of blood and colloid given intraoperatively. However the degree of metabolic disturbance does not appear to be related to the duration of surgery.

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This suggests that it is difficult to predict which patients will develop a greater or persistent metabolic acidosis by length of surgical procedure alone. Intravenous propofol was not used to maintain anaesthesia and therefore it is unlikely that any metabolic disturbance was due to a propofol infusion syndrome.

We designed the study protocol around current practice without additional resources or intervention apart from the data collection sheets. Chloride and lactate are not routinely measured with the iSTAT® cartridges in current use, so we based our assessment of metabolic change without these parameters. We are therefore unable to define a more specific nature of the metabolic disturbance, such as hyperchloraemic acidosis, lactic acidosis or ketoacidosis. Although perioperative acidosis is suggestive of end organ hypoperfusion it is important to distinguish ongoing tissue hypoxia from hyperchloraemic metabolic acidosis secondary to fluid infusion because they should be managed differently. The correct interpretation of an abnormal base deficit in a surgical patient may be difficult to disentangle because of its multifactorial nature. A physicochemical approach to analysis of acid-base disturbance may be helpful in distinguishing the aetiologies (11). Of direct relevance to this study is the work by Brill et al which suggests that base deficit does not predict mortality when secondary to hyperchloraemic acidosis (12). Future studies which incorporate additional laboratory analysis would be needed to evaluate the base deficit in more detail.

Patients undergoing monobloc/fronto-facial advancement surgical procedures, which are carried out less frequently in our institution, may be investigated as a separate group in future studies in order to compare blood loss and fluid requirements and metabolic changes.

This study is the first documented data on metabolic changes during major craniofacial surgery. It did not intend to analyse the aetiology of the changes nor specify a threshold of base deficit that would trigger a decision to admit to a high dependency unit. As with many biochemical measurements, the data should be looked at on an individual basis in conjunction with data trends and clinical assessment of each patient.

Our data from this study has confirmed the presence of marked metabolic disturbance, in both degree and duration, during major elective paediatric craniofacial procedures. This is associated with considerable intraoperative blood loss and volume replacement, and as a useful marker of physiological derangement, it can remain significant for several hours into the postoperative period. Biochemical data should not be viewed without reference to clinical review. All patients undergoing major craniofacial surgery in our Trust continue to have monitored overnight postoperative care on the high dependency unit.

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For Peer Review

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TABLE 1. Summary of data

	Median	Range
Age (months)	19	4 - 204
Duration of surgery (hours)	3.1	1.2 - 7.8
Initial BD	-4	-7 - +1
Maximum BD	-9	-20 - -3
Time to maximum BD (hours)	3.5	0 - 11.5
Time from maximum BD to normal (hours)	9.25	0 - 18
Duration of significant BD (hours)	3.8	0 - 20
Total intraoperative volume blood+colloid (ml/kg)	55	10 - 148