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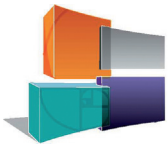

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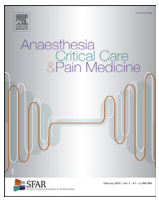

Original Article

Use of near-infrared spectroscopy in predicting response to intravenous fluid load in anaesthetized infants

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ABSTRACT

Introduction: The prediction of fluid responsiveness in paediatrics and infants remains problematic. We sought to test the validity of the measurement of $StcO_2$ as a predictive parameter of fluid responsiveness in infants less than one year old during non-cardiac surgery.
Materials and methods: This was a prospective observational study on infants aged less than 1 year without any cardiac disease during the intraoperative period of non-cardiac surgery. Cerebral oxygen saturation ($StcO_2$) was obtained using infrared spectroscopic INVOS® monitors. Reference values were obtained 10 minutes after intubation. Fluid load indications were dependent on the anaesthesiologist caring for the patient. The objective of this study was to determine the accuracy of $StcO_2$ values before vascular filling ($StcO_2B$) and the difference in $StcO_2$ values between the reference value and before vascular filling ($\Delta StcO_2$), in predicting vascular filling response defined as an increase in mean arterial pressure over 15%. Statistical analysis was carried out using ROC curve analysis with determination of grey zones.
Results: Twenty-nine patients were eligible for this study, 23 were included in the study (one intravenous fluid challenge per patient). There were 10 responders and 13 non-responders. The $StcO_2B$ and the $\Delta StcO_2$ were significantly different between responders and non-responders. Analysis of the ROC curve found an area under the curve of 0.75 [95% CI 0.56 to 0.95] for $StcO_2B$ and 0.83 [95% CI 0.66 to 0.99] for $\Delta StcO_2$. The grey-areas were [59–78] and [16–28] for $StcO_2B$ and $\Delta StcO_2$.
Conclusion: NIRS appears to be an interesting additional tool for predicting an increase of blood pressure in response to intraoperative fluid challenge in infants less than one year old.

1. Introduction

The diagnosis of hypovolaemia during paediatric anaesthesia remains challenging, especially in younger patients. Classical parameters are still relied upon, namely: noninvasive and invasive blood pressure, heart rate, central venous pressure (when available) and urine output. However, these factors have been widely shown to have a poor predictive value in detecting hypovolaemia [1]. Moreover, the effects of hypovolaemia and hypotension on cerebral haemodynamics and oxygenation are still poorly characterized during non-cardiac surgery in infants and children [2–4]. The cerebral autoregulation that maintains cerebral perfusion during pressure variations can be impaired during hypotension [5,6]. Importantly, this pressure threshold depends on many factors, such as age and illness conditions [7–9]. Autoregulation impairment during hypotension might increase oxygen extraction that can be identified by measuring jugular or cerebral oxygen saturation [10,11].

Recent reports have emphasized a strong association between hypotension and bad neurological outcome after cardiac and non-cardiac surgery in adults, children and infants [12,13]. In addition,

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preventing hypovolaemia using haemodynamic goal-directed therapy has been widely shown to decrease postoperative complications [14]. Consequently, preventing hypovolaemia and hypotension are important targets in managing intraoperative anaesthesia.

During the last decade, the measurement of tissue oxygenation (StO_2) using near-infrared spectroscopy technology has become possible and many devices are now available for this purpose [15–18]. Many studies in adults and children have shown potential benefits associated with the monitoring of regional brain oxygenation for detecting intraoperative cerebral oxygenation ($StcO_2$) decreases and guiding intensive care transfusion therapy [4,17]. Moreover, using these devices, many authors have found an association between cerebral oxygenation impairment and the worsening of neurological outcome, especially during cardiac surgery and head trauma [19,20]. The aim of the present work was to assess the accuracy of cerebral oxygenation monitoring in predicting an increase in blood pressure induced by intravenous fluid load during anaesthesia for non-cardiac surgery in neonates and infants less than one year old.

2. Material and methods

This prospective, monocentric, observational study was approved by our IRB (Comité d'Évaluation de l'Éthique des projets de Recherche Biomédicale (CEERB) de Robert-Debré; # 12-021) and the French national data protection committee. Written informed consent was waived by the institutional ethics committee but parents were informed about the study and their oral consent was obtained for all included patients.

2.1. Inclusion criteria

Patients were prospectively and consecutively included if they fulfilled the following criteria: postnatal age less than or equal to 12 months, ASA status 1 or 2, operated under general anaesthesia and needing an intraoperative fluid challenge. Patients were excluded if they were operated in a prone position, presented known neurological abnormalities (including prematurity defined as a gestational age of less than 37 weeks at birth) or had known cardiac, vascular or kidney diseases (heart failure, hypertension or renal failure).

2.2. Intraoperative anaesthesia management

All patients, except those undergoing emergency surgeries, with full stomachs or those less than 30 days postnatal age, were pre-medicated with oral Hydroxyzine 2 $mg.kg^{-1}$ given 60 to 120 minutes before the expected time of induction. For scheduled interventions and according to our local protocol, patients were allowed to eat solids and to freely drink non-particulate liquids until 6 and 2 hours before anaesthesia induction, respectively.

The anaesthesia protocol was standardized. Anaesthesia monitoring included heart rate (HR), noninvasive blood pressure monitoring (Carescape Monitor B650, General Electrics Healthcare, Fairfield, CT 06828, USA) on the left or right arm, arterial saturation, end tidal CO_2 ($ETCO_2$), gas monitoring (sevoflurane, O_2 and N_2O concentrations), respiratory monitoring (tidal volume and peak airway pressures), cerebral oxygen saturation ($StcO_2$, using the INVOS system: Covidien, Levallois-Perret, France, with neonatal probes placed in the median frontal region) and temperature measurement using a rectal or oesophageal probe. All patients underwent three minutes pre-oxygenation. Anaesthesia induction was performed using inhaled or intravenous approaches. Anaesthesia maintenance was performed using sevoflurane (0.8 to 1 adjusted MAC) in a mixture of O_2/N_2O 50%/50%. Ventilation was maintained using a pressure-controlled mode without end-expiratory pressure (as stated by our local protocol). The end tidal CO_2 concentration was targeted between 30 and 35 mmHg by varying the respiratory frequency and peak airway pressure (maintained between 10 and 18 cmH_2O). Intraoperative analgesia was achieved by sufentanil boluses. Patients were actively warmed from the time they entered the operating room and until they left the operative theatre.

2.3. Intraoperative fluid intake management

Intraoperative fluid management consisted of crystalloids (Ringer lactate and 1% glucose) administered according to Holliday and Segar formulae [21] with compensation for the preoperative fasting period and fluid losses related to surgery (an additional 6 $mL.kg^{-1}.h^{-1}$). Given that intraoperative sevoflurane concentrations were maintained within therapeutic ranges and that any surgical compression was eliminated, most intraoperative haemodynamic impairments were considered to involve absolute or relative hypovolaemia. Intraoperative fluid boluses were performed according to the judgment of the anaesthesiologist caring for the patient. The latter relied on classic haemodynamic parameters: decrease of arterial pressure of more than 20% in comparison to pre-induction values, decrease of $ETCO_2$ or increased heart rate and any intraoperative situation indicating fluid load (long duration of laparotomy surgery, intestinal occlusion). Each bolus consisted of 10 $mL.kg^{-1}$ of normal saline solution given over 15 minutes using a calibrated pump. In case of failure to restore target parameters after two consecutive boluses, sevoflurane end tidal concentration was decreased.

2.4. Data collected

Demographic data (age, weight), the surgery performed and duration of surgery were recorded. For each fluid challenge, the following parameters were recorded before and after the fluid challenge: heart rate (HR), systolic blood pressure, diastolic blood pressure, mean blood pressure, respiratory rate, arterial haemoglobin saturation, $ETCO_2$, cerebral oxygen saturation ($StcO_2$, the mean of 3 measurements), sevoflurane expiratory concentration and body temperature. In addition, these haemodynamic and respiratory parameters were also recorded for each of the following periods: before induction, after the pre-oxygenation period, after intubation and 10 minutes after intubation.

2.5. Statistical analysis

The primary goal of the present study was to assess the performance of $StcO_2$ before the fluid challenge ($StcO_2B$) and the difference between $StcO_2$ 10 minutes after intubation and before fluid challenge ($\Delta StcO_2$) for predicting fluid therapy responsiveness. An increase of mean arterial pressure of more than 15% was considered as a positive response to the fluid load. Otherwise, the child was considered as a non-responder. The secondary endpoint was the variability of $StcO_2$ during fluid challenges in responders and non-responders.

The sensitivity and specificity (and their 95% confidence intervals) for each value of $StcO_2B$ and $\Delta StcO_2$ were used to construct a receiver operating characteristic (ROC) curve and to determine the area under the curve (AUC). Using the previously described gray zone method [22], we determined the optimal values of $StcO_2B$ and $\Delta StcO_2$ predicting a response or the absence of response to a fluid challenge. Basically, this methodology relies on determining ranges of explored parameter values that minimize the risk of misclassifying both positive and negative challenges