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Does metabolic alkalosis influence cerebral oxygenation in infantile hypertrophic pyloric stenosis?

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ABSTRACT

Background: This pilot study focuses on regional tissue oxygenation (rSO_2) in patients with infantile hypertrophic pyloric stenosis in a perioperative setting. To investigate the influence of enhanced metabolic alkalosis (MA) on cerebral (c-rSO_2) and renal (r-rSO_2) tissue oxygenation, two-site near-infrared spectroscopy (NIRS) technology was applied.

Materials and methods: Perioperative c-rSO_2, r-rSO_2, capillary blood gases, and electrolytes from 12 infants were retrospectively compared before and after correction of MA at admission (T1), before surgery (T2), and after surgery (T3).

Results: Correction of MA was associated with an alteration of cerebral oxygenation without affecting renal oxygenation. When compared to T1, 5-min mean (± standard deviation) c-rSO_2 increased after correction of MA at T2 (72.74 ± 4.60% *versus* 77.89 ± 5.84%; $P = 0.058$), reaching significance at T3 (80.79 ± 5.29%; $P = 0.003$). Furthermore, relative 30-min c-rSO_2 values at first 3 h of metabolic compensation were significantly lowered compared with postsurgical states at 16 and 24 h. Cerebral oxygenation was positively correlated with levels of sodium ($r = 0.37$; $P = 0.03$) and inversely correlated with levels of bicarbonate ($r = -0.34$; $P = 0.05$) and base excess ($r = -0.36$; $P = 0.04$). Analysis of preoperative and postoperative cerebral and renal hypoxic burden yielded no differences. However, a negative correlation ($r = -0.40$; $P = 0.03$) regarding hematocrite and mean r-rSO_2, indirectly indicative of an increased renal blood flow under hemodilution, was obtained.

Conclusions: NIRS seems suitable for the detection of a transiently impaired cerebral oxygenation under state of pronounced MA in infants with infantile hypertrophic pyloric stenosis. Correction of MA led to normalization of c-rSO_2. NIRS technology constitutes a promising tool for optimizing perioperative management, especially in the context of a possible diminished neurodevelopmental outcome after pyloromyotomy.

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Introduction

The prevalence of infantile hypertrophic pyloric stenosis (IHPS) in Germany is about 2.29 per 1000 live births.[1] Mature infants of normal gestation and age-related birth weight are mostly affected.[2,3] Postprandial propulsive, nonbilious vomiting is a leading symptom. Impaired gastric emptying because of hypertrophy of the pyloric muscle causes loss of gastric contents as hydrochloric acid, water, and electrolytes, resulting in hypochloremic metabolic alkalosis (MA) and dehydration.[2,4] Preoperative replacement of water and electrolytes is required to restore homeostasis. Laparoscopic approach of extramucous surgical splitting of the hypertrophic pyloric muscle under general anesthesia is the therapy of choice. Currently, there is only little knowledge of a possible influence of alkalosis on cerebral and renal oxygenation in children suffering for IHPS. However, several *in vivo* and *in vitro* studies postulate the cerebral blood flow (CBF) to be influenced by alteration of pH and pCO_2 (extensively reviewed by Yoon *et al.* and Willie *et al.*).[5,6] The aim of this study was to evaluate perioperative cerebral and renal oxygenation in infants with IHPS before and after correction of MA, using noninvasive near-infrared spectroscopy technique (NIRS). In previous investigations, NIRS served as a useful tool for continuous estimation of regional tissue oxygenation (rSO_2). Furthermore, we interpret our data under the light of the latest results of neurodevelopmental research.

Materials and methods

Patients

In a retrospective observational pilot review, we identified 12 children with IHPS and MA in whom cerebral and renal NIRS monitoring was performed in an arbitrary manner between January 2013 and March 2015. IHPS was assumed clinically and confirmed by ultrasound investigation and intraoperatively in each case. In all infants, general anesthesia was performed during laparoscopic procedure.

Methods

We used the INVOS 5100C device (Covidien, Mansfield, MA) using the right forehead (c-rSO_2) and right Th10-L2 flank (r-rSO_2) probe placement (OxyAlert Neonatal NIRSensor, Covidien; data sampling mode at approximately 0.16 Hz). During NIRS recording period, body temperature and transcutaneous SaO_2 remained within normal ranges (data not shown). Capillary blood gas and electrolyte analysis was routinely performed with the GEM Premier 4000-Device (Instrumentation Laboratory, Lexington, MA). Blood gas sampling was obtained via puncture of the lateral distal portion of the heel–finger using heparinized 170-μL capillary tubes (IL-Instrumentation Laboratory SpA, Milano, Italy). The estimated parameters included the hemoglobin concentration (Hb), hematocrit (Hct), acid–base status (pH, base excess [BE], partial pressure of carbon dioxide [pCO_2], standard bicarbonate [HCO_3^-]), levels of glucose and lactate, ion concentrations of sodium [Na^+], potassium [K^+], and chloride [Cl^-]. The presence of MA was defined as pH > 7.45 and HCO_3^- >26 mmol/L. Data sampling and analysis were performed using INVOS Analytics Tool Version 1.2.1 (Covidien, Mansfield, MA) and Excel 2010 (Microsoft Co., Redmond, WA). Statistical analysis and graph plotting were performed with Origin Pro 9.0 software (OriginLab, Northampton, MA). For quantification of data, three different time points were predefined, comparing initial state of uncorrected MA at time point 1 (T1) with state of metabolic compensation before (T2) and after surgery (T3). T1 represents start of NIRS monitoring at admission with simultaneously obtained capillary blood gas analysis. T2 represents state of metabolic compensation before surgery under fluid resuscitation (intravenous administration of 5%-glucose isotonic-balanced electrolyte solution without buffer, 200 mL/kg/d) with simultaneously derived normalized blood gases and electrolytes. T3 marks steady state of metabolic homeostasis after surgery at transition to oral bolus feeding. For analysis of sampled rSO_2 raw data, a 5-min average was taken at corresponding time points of concurrent blood gas analysis. Taking account of the prescribed high degree of intraindividual and interindividual variability of NIRS values,[7,8] a 30-min average of rSO_2 raw data were elicited additionally, thus minimizing likelihood of short-term variability. To improve interindividual comparability, data underwent further normalization. For each patient, 30-min mean rSO_2 at T2 or T3 was divided by corresponding reference data at T1. In addition, we analyzed a larger time scale of 30-min rSO_2 data during restoration of metabolic homeostasis, starting with first 3 h of measurement, continued by the last 3 h before surgery and concluded at 16 and 24 h post-surgery. Relative change of values was obtained by taking the quotient of individual values at subsequent time points and their reference obtained at first time point (0.5 h). Further analysis was focused on estimation of hypoxic burden. The rSO_2 desaturation score indicates the extent of hypoxic burden and is calculated by multiplication of rSO_2 (percentage) below a predefined threshold by the time (minutes) of its occurrence. The rSO_2 desaturation score is an area under the curve measurement, accounting for depth and duration of desaturation below the predefined saturation threshold. Because of a broad bandwidth of critical baselines in different studies, Ruf *et al.* suggested the critical lower baseline of healthy infants in cerebral NIRS to be set at 55% and the somatic value at 65% rSO_2 for renal NIRS.[9] Because of different individual duration for metabolic compensation, and therefore varying sampling time, data underwent normalization by the amount of individual recording time (hours) stated as min-%/h.

Statistics

Demographic data are presented as median and range or as individual parameters. For further data description, we used the arithmetic mean ± standard deviation unless stated otherwise. For graphical demonstration, we used box and whisker plots depicting median, interquartile range, and outliners of the corresponding variable. Normal distribution of all parameters was confirmed by Kolmogorov–Smirnov