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Clinical Research

The Role of Regional Oxygen Saturation Using Near-Infrared Spectroscopy and Blood Lactate Levels as Early Predictors of Outcome After Pediatric Cardiac Surgery

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ABSTRACT

Background: The purpose of the study was to evaluate the association between regional oxygen saturation (rSO_2) desaturation score (calculated by multiplying the $rSO_2 < 50\%$ by time in seconds the preoperative baseline value) measured with near-infrared spectroscopy and the peak of lactate with postoperative major morbidities in pediatric patients who undergo cardiac surgery.

Methods: We retrospectively analyzed the postoperative course of 152 patients between January 2012 and December 2013, for whom we continuously monitored cerebral rSO_2 using near-infrared spectroscopy and serial arterial blood lactate levels for at least 48 hours.

Results: The median age at surgery was 128 days (interquartile range [IQR], 17-537 days). Thirty-nine patients had a single ventricle physiology (26%) and 135 patients (89%) required the use of cardiopulmonary bypass (median time of 130 minutes; IQR, 93-172 minutes). Median postoperative peak lactate level was 3 mmol/L (IQR,

RÉSUMÉ

Introduction : Cette étude avait pour objectif d'évaluer l'association entre le score de désaturation de la rSO_2 (saturation cérébrale régionale en oxygène) (calculé en multipliant la $rSO_2 < 50$ % par le délai en secondes de la valeur préopératoire de départ) mesurée par spectroscopie proche infrarouge et la concentration maximale de lactate, d'une part, et la présence de morbidités graves chez de jeunes patients ayant subi une chirurgie cardiaque, d'autre part.

Méthodes : Nous avons procédé à une analyse rétrospective de l'évolution postopératoire de 152 patients opérés entre janvier 2012 et décembre 2013 et qui avaient bénéficié d'une surveillance continue de la rSO_2 cérébrale par spectroscopie proche infrarouge et d'une vérification sériée de la concentration de lactate sanguin artériel pendant au moins 48 heures.

Résultats : L'âge médian des jeunes patients au moment de la chirurgie était de 128 jours (écart interquartile [EQ], 17 à 537 jours).

Microcirculatory disturbances after cardiac surgery are thought to be at the origin of organ dysfunction.[1,2] Different strategies for monitoring patients after congenital heart surgery have evolved considerably during the past decade and near-infrared spectroscopy (NIRS) has been developed as a noninvasive diagnostic method for in vivo monitoring of regional oxygen saturation (rSO_2).[3-5] rSO_2 measured using NIRS is used as a potential surrogate for cerebral and somatic mixed venous oxygen saturation and it has been suggested as a noninvasive tool to continuously monitor and detect states of low body perfusion.[6-8] Slater and coworkers[9] first showed how a prolonged rSO_2 desaturation score (time in seconds < 50% saturation threshold) in adult patients was significantly associated with an increased risk of postoperative morbidities defined as cognitive decline and prolonged hospital stay after cardiac surgery.

Methods

The Clinical Investigation Committee from the University Hospital of Padua approved the review process of medical records and computerized hospital data. The study procedures were in accordance to the institutional guidelines for

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2-5.3 mmol/L); 52 patients (34%) had a postoperative lactate level > 4.6 mmol/L. The median postoperative rSO_2 desaturation score was 157 (IQR, 0-2050); 62 patients (41%) had an rSO_2 desaturation score > 345. Fifty-seven patients (37%) had postoperative major morbidities. Using a multivariable regression model only rSO_2 desaturation score > 345 was independently associated with major morbidities after surgery (odds ratio, 27.26; 95% confidence interval, 10.18-73.00). The proportion of patients with an rSO_2 desaturation score > 345 within 240 minutes after surgery was higher than the rate of those who showed a peak of lactate > 4.6 mmol/L (84% vs 59%; $P = 0.05$).

Conclusions: The postoperative rSO_2 desaturation score has a stronger association with major postoperative morbidities than lactate and it also provides an earlier warning sign of hemodynamic or metabolic compromise.

Trente-neuf patients avaient un cœur univentriculaire (26 %), tandis que 135 patients (89 %) avaient nécessité un pontage cardiopulmonaire (délai médian de 130 minutes; EQ, 93 à 172 minutes). La concentration maximale médiane de lactate postopératoire était de 3 mmol/l (EQ, 2 à 5,3 mmol/l); 52 patients (34 %) ont présenté une concentration de lactate postopératoire > 4,6 mmol/l. Le score médian de désaturation de la rSO_2 postopératoire s'élevait à 157 (EQ, 0 à 2050); 62 patients (41 %) ont présenté un score de désaturation de la rSO_2 > 345. Cinquante-sept patients (37 %) ont présenté de graves morbidités postopératoires. Grâce à une analyse de régression multivariée, on a constaté que seul le score de désaturation de la rSO_2 > 345 était associé de manière indépendante à d'importantes morbidités postopératoires (rapport d'incidence approché, 27,26; intervalle de confiance à 95 %, 10,18 à 73,00). La proportion des patients qui ont présenté un score de désaturation de la rSO_2 > 345 dans les 240 minutes ayant suivi la chirurgie était supérieure à celle des patients qui présentaient une concentration de lactate postopératoire > 4,6 mmol/l (84 % *vs* 59 %; $p = 0,05$).

Conclusion : Le score de désaturation de la rSO_2 postopératoire est plus fortement associé aux morbidités postopératoires importantes que la concentration de lactate, et constitue également un signal d'alarme plus précoce d'une défaillance de l'équilibre hémodynamique ou métabolique.

retrospective data collection and protection of patient confidentiality.

A convenience sample of 152 pediatric patients (younger than 16 years) who underwent complex surgery for congenital heart disease between January 2012 and December 2013 were considered for the analysis. We included patients who underwent combined continuous cerebral rSO_2 motoring with NIRS for the duration of the surgery and during the first 48 hours in the intensive care unit (ICU) and serial detection of arterial blood lactate levels (using a standard arterial blood gas analysis). Blood samples were examined every 60 minutes during the surgery, every 2 hours during the first 24 hours, and every 4 hours during the 24 hours after surgery. We excluded patients with simple congenital heart disease (**R**isk **A**djusted classification for **C**ongenital **H**eart **S**urgery [RACHS] score = 1; n = 77). The RACHS was created to compare in-hospital mortality for groups of children who underwent surgery for congenital heart disease. This method stratifies anatomic diversity into 6 categories on the basis of age, type of surgery performed and similar in-hospital mortality.[10]

We also excluded patients: (1) with preoperative arterial blood lactate level > 3 mmol/L (n = 51); (2) not monitored with NIRS (n = 32); and (3) who spent < 48 hours in the ICU or whose rSO_2 was monitored for < 48 hours (n = 88; Fig. 1).

The INVOS 5100C oxymeter (Covidien, Mansfield, MA) was used for measurement of intra- and postoperative (48 hours after surgery) cerebral (sensor on the forehead) rSO_2. Two types of disposable sensors were used: (1) the neonatal sensor for patients with body weight ≤ 5 kg (OxyAlert NIRS-Cerebral neonatal regional oxygen saturation sensor; Covidien); and (2) the pediatric sensor for patients with body weight > 5 kg (SomaSensor, Pediatric Cerebral/Somatic sensor; Covidien). The sensor was applied in the operating room and used to monitor the operative and postoperative course of each patient in the ICU. The maximum lactate level reached as well as the peak rSO_2 desaturation score were recorded along with the time when they occurred. An rSO_2 desaturation score was calculated, as suggested by Slater et al.,[9] by multiplying the rSO_2 < 50% of the preoperative baseline value of every single patient, by time in seconds.

Demographic data (age and weight at the time of surgery, sex), physiologic data (type of physiology as single-ventricle vs 2-ventricle physiology), preoperative laboratory data (including hematocrit, prothrombin time, serum creatinine value), operative data (cardiopulmonary bypass [CPB] time, cross-clamp time, and circulatory arrest times) were collected for each patient.

The purpose of this study was to identify the optimal predicted probability cutoff for the postoperative rSO_2 desaturation score and the peak of lactate level in detecting postoperative major morbidities, defined as death, the need for leaving the chest open after surgery (requiring late sternal closure), low cardiac output syndrome (defined as a transient decrease in systemic perfusion secondary to myocardial dysfunction leading to impaired peripheral circulation, vasoconstriction, reduced urine output [< 0.5 cc/kg], metabolic acidosis with hyperlactacidemia),[11] extracorporeal membrane oxygenation requirement (ECMO), acute renal failure requiring renal replacement therapy, pulmonary complications (including acute respiratory distress syndrome, respiratory infections, and pulmonary hypertension requiring inhaled nitric oxide), arrhythmic complications (including persistent or temporary complete atrioventricular block and ventricular fibrillation), and bleeding requiring surgical reintervention.

A **St**rengthening the **R**eporting of **Ob**servational Studies in **E**pidemiology (STROBE) statement (checklist of items that should be included in reports of observational studies) was created (Supplemental Table S1).

Descriptive data and major complications are reported as absolute and relative frequencies and median values with