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Near-infrared spectroscopy cerebral and somatic (renal) oxygen saturation correlation to continuous venous oxygen saturation via intravenous oximetry catheter☆

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Abstract

Purpose: Near-infrared spectroscopy (NIRS) and continuous central venous oxygen saturation ($ScvO_2$) via oximetry catheter are 2 modalities available to estimate adequacy of oxygen delivery in postoperative pediatric cardiac patients. Near-infrared spectroscopy measures regional tissue oxygenation and is routinely used in pediatric cardiac surgery patients. By not requiring an invasive catheter, NIRS has the advantage over mixed venous oxygen saturation (SvO_2) monitoring. An alternative marker of global tissue oxygenation is central venous oxygen saturation ($ScvO_2$). A recently developed pediatric-sized oximetric catheter (PediaSat; Edwards Lifesciences, Irvine, CA, USA) functions as a central venous catheter and provides a continuous $ScvO_2$ reading, an accepted surrogate to SvO_2. To date, the correlation between NIRS and $ScvO_2$ has not been quantified. The aim of this study was to examine the strength of the bivariate correlation between NIRS and $ScvO_2$ measurements.

Design/methods: Twenty pediatric patients undergoing cardiac surgery had the PediaSat catheter placed with the tip in the superior vena cava and NIRS sensors (cerebral and renal) placed in the operating room per routine protocol. Hourly measurements of NIRS-cerebral (NIRS-C), NIRS-renal, and $ScvO_2$ readings were recorded for each patient for up to 48 hours postoperatively.

Results: A cumulative total of 630 hours of data were collected. Spearman correlation coefficients for NIRS-renal vs $ScvO_2$ and NIRS-C vs $ScvO_2$ measurements were $r = 0.38$ ($P = .09$) and $r = 0.58$ ($P < .008$), respectively.

Conclusions: In this small cohort of pediatric patients undergoing heart surgery, there was a moderate but statistically significant correlation between the $ScvO_2$-catheter and the NIRS-C values. Further studies are required to determine which oxymetric modality of monitoring cardiac output most aids in the postoperative management of these patients.

☆ Research was conducted at the Inova Fairfax Hospital for Children, Falls Church, Va.

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1. Introduction

1.1. Background

Many noninvasive modalities of monitoring cardiac output in pediatric cardiac patients have been developed over the last few decades to assist in the management of these patients intra- and postoperatively. Of the 3 determinants of oxygen delivery (cardiac output, hemoglobin level, and arterial oxygenation), cardiac output is one of the most difficult to measure noninvasively. Two technologies that use measurements of oxygenation in somatic tissue beds and in a central vein are being used to help assess cardiac output in pediatric cardiac patients.

Near-infrared spectroscopy (NIRS) measures the percentage of oxygenated vs deoxygenated hemoglobin level in tissue beds and is used to determine cerebral tissue oxygen saturation (NIRS-cerebral [NIRS-C]) and renal somatic tissue oxygen saturation (NIRS-renal [NIRS-R]) via sensors placed on the patients' forehead and the renal somatic area. Similar to a central mixed venous oxygen value, the NIRS-C and NIRS-R readings reflect a largely venous measure of tissue oxygen and therefore give an indication of the balance of oxygen supply and consumption in the tissue beneath the sensor. Measurement of NIRS-C has been correlated with jugular venous saturation in animals [1] and to jugular venous saturation and hemodynamics in humans [2,3]. This technology, which was approved for pediatric use in 2005, has gained acceptance and is becoming more widespread in pediatric operating rooms, pediatric intensive care units, and cardiovascular intensive care units [4,5]. Evidence to date suggests that NIRS monitoring has provided real-time clinical benefits in the care of pediatric cardiac patients [3,5-7].

Central mixed venous oxygen saturation (SvO_2) from a pulmonary artery sample is widely accepted as a marker of global tissue perfusion. However, its measurement requires placement of a pulmonary artery catheter, which is not otherwise standard of care in most pediatric patients. Central venous oxygenation as measured from co-oximetric blood samples withdrawn from central lines (central venous oxygen saturation [$ScvO_2$]) and placed in the superior vena cava (SVC), inferior vena cava, or right atrium has, therefore, been used as a surrogate to the SvO_2 measurement in critically ill pediatric patients [5,8-11]. A recently developed, pediatric-sized central venous catheter (PediaSat catheter; Edwards Lifesciences) allows the measurement of the percentage of oxygenated and deoxygenated hemoglobin levels in the blood using reflection spectrophotometry and is able to do so in a continuous $ScvO_2$-catheter reading. Placement of this catheter in pediatric cardiac patients undergoing operative procedures is no different from placing a standard nonfiberoptic central venous catheter [10]. The continuous $ScvO_2$-catheter readings from the SVC has been found to correlate with serial co-oximetric measurements taken via blood samples ($ScvO_2$-blood) in pediatric patients and also with changes in cardiac index in anesthetized pigs [12-14]. In addition, continuous measurement of SvO_2 and $ScvO_2$ via intravenous fiberoptic catheters has been found to correlate with each other in critically ill adults [15].

1.2. Objective

To date, no literature exists examining the possible correlation of the tissue and mixed venous oxygenation measurements of the NIRS and pediatric fiberoptic $ScvO_2$-catheter technology. The aim of this observational study was to quantify the correlation between NIRS tissue oxygenation (NIRS-C and NIRS-R) and $ScvO_2$-catheter measurements. A secondary aim was to examine the correlation between the $ScvO_2$-catheter and $ScvO_2$-blood samples.

2. Methods

2.1. Patient selection

Between September 2008 and June 2009, 20 consecutive pediatric patients undergoing cardiac surgery at Inova Fairfax Hospital for Children were prospectively enrolled. All patients had the $ScvO_2$-catheter (PediaSat) placed in the operating room in either the subclavian or internal jugular veins with the tip positioned in the SVC. Near-infrared spectroscopy sensors (cerebral and renal) were also placed in the operating room. Informed consent was obtained from the parents before surgery. Confirmation of proper position of the tip of the $ScvO_2$-catheter was ascertained via chest radiograph upon arrival in the pediatric intensive care unit. No patients were excluded for malposition of the catheter tip. The Inova Health System Institutional Review Board approved the study protocol.

2.2. Interventions

Managing physicians were not blinded to the placement of these oxymetric modalities. They were also free to manage these patients using all of the oxymetric data as they saw fit. Central venous oxygen saturation–catheter size and number of lumens were determined in the operating room by the pediatric anesthesiologist and pediatric cardiac surgeon. These catheters were cared for as per standard pediatric intensive care unit central line protocols. Near-infrared spectroscopy sensor pads were similarly cared for per standard protocol in our pediatric intensive care unit.

2.3. Outcomes and measurements

Hourly measurements of NIRS-C, NIRS-R, and $ScvO_2$-catheter readings were recorded for each patient for up to 48 hours postoperatively. Measurements of arterial blood gas, hematocrit, and $ScvO_2$-blood were recorded if available. Ventilated patients also had FiO_2, positive end expiratory pressure, and mean airway pressure recorded when arterial blood gases were drawn.