Case Report

Near-Infrared Spectroscopy: An Important Tool during the Blalock-Taussig Shunt

Abstract

Near infra red spectroscopy (NIRS) is a noninvasive diagnostic tool for measuring regional oxygen saturation (rSO2). Cerebral oxygenation measured with NIRS is used to corroborate mixed venous oxygenation and hence considered an indicator of tissue perfusion. We describe NIRS guiding an anatomical variation leading to inadequate cerebral circulation or any impairment in cerebral oxygen delivery during Blalock Taussig shunt.

Keywords: *Blalock-Taussig shunt, near-infrared spectroscopy, regional cerebral oxygen saturation*

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Introduction

Near-infrared spectroscopy (NIRS) is a noninvasive diagnostic tool for measuring regional oxygen saturation (rSO_2) and is primarily used for assessing cerebral oxygenation. Cerebral oximetry (regional cerebral oxygen saturation [$rScO_2$]) has been used to corroborate with mixed venous oxygenation and is a surrogate of adequate tissue perfusion.[1,2] It further acts as a first monitoring tool to detect overflow or underflow through the shunt. We describe NIRS as a monitor to detect impairment in cerebral oxygen delivery during or after the Blalock-Taussig shunt (BTS) intraoperatively.

Case Reports

Case 1

A full-term 3-day-old, 3 kg, male child presented to our unit with a history of cyanosis since birth. Echocardiography revealed pulmonary artesia, ventricular septal defect (VSD) with patent ductus arteriosus (PDA) supplying confluent branch pulmonary arteries. Baby maintained oxygen saturation (SpO_2) of 84%–88% on prostaglandin E 1 (PGE-1) infusion.

After primary workup, the patient was scheduled for the right modified BTS (RMBTS). Standard monitoring as per the American Society of Anaesthesiology (ASA) protocol was established with pulse oximetry in the left upper limb. After routine intravenous (IV) induction, central venous access in the right internal jugular vein and right femoral arterial lines were secured, and bilateral frontal $rScO_2$ were monitored with SenSmart® NONIN. Baseline $rScO_2$ post induction was 75 (left) and 74 (right) on FiO_2 of 0.5 with a mean arterial pressure (MAP) of 55 mmHg. The patient was placed in right thoracotomy and heparin (100 U/kg) given before clamping of innominate artery to achieve a target activated clotting time of 200 s. Thereafter, a 4-mm polytetrafluoroethylene shunt was placed between the right innominate artery and superior aspect of the right pulmonary artery (RPA). PGE-1 infusion was discontinued as soon as flow across BTS was established. Soon thereafter drop in $rScO_2$ values on the right side ($rScO_2$ 66) with no change in the left $rScO_2$ was noted. Along with falling right $rScO_2$ wide pulse pressure, rising trends of end-tidal carbon dioxide $EtCO_2$ (about 20% rise from the baseline), a $SpO_2$of 95% on FiO_2 0.6, and STT changes (ST depression of 2–3 mm) were also noticed.

This fall in $rScO_2$ on the right side was considered to be caused by preferential blood flow to BT shunt at the expense of cerebral oxygen delivery, though it normalized after 30 min.

During this episode of falling ipsilateral $rScO_2$ measures such as decreasing FiO_2,

How to cite this article: Lamba A, Joshi RK, Joshi R, Agarwal N. Near-infrared spectroscopy: An important tool during the Blalock-Taussig shunt. Ann Card Anaesth 2020;23:92-4.

Submitted: 10-Jul-2018
Revised: 28-Sep-2018
Accepted: 26-Oct-2018
Published: 07-Jan-2020

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Access this article online

Website: www.annals.in

DOI: 10.4103/aca.ACA_138_18

Quick Response Code:

controlled hypercapnia so as to increase pulmonary vascular resistance were taken [Figure 1].

Case 2

A 3-day-old, 2.9 kg full-term male child presented to our unit in cyanotic spell (SpO_2 40%) and poor peripheral perfusion. Echocardiography revealed tetralogy of Fallot, severely obstructed and hypoplastic right ventricular outflow tract with small PDA. Pt was intubated and PGE-1 infusion started thereafter. Dopamine (5 mcg/kg/min) was initiated in view of hemodynamic instability. The patient was scheduled for emergency RMBTS as there was little improvement in SpO_2 despite maximal dose of PGE-1.

Bilateral frontal cerebral oximetry was monitored along with standard ASA monitoring and patient was positioned in the right thoracotomy position. Baseline $rScO_2$ postinduction was 76 (left) and 77 (right side) on FiO_2 of 0.7 with MAP of 40 mmHg.

No change in $rScO_2$ values was noted when the clamp was applied on right subclavian artery to construct proximal anastomosis. For constructing distal anastomosis, RPA was isolated by occluding the first order branches and proximal RPA sequentially. On proximal RPA clamping $rScO_2$ value decreased to significant levels (right $rScO_2$ 60 and left $rScO_2$ 64) with subsequent fall in SpO_2 (60%) though MAP of 60 mmHg was maintained.

The fall in NIRS was communicated to the surgical team who noticed a right-sided ductal insertion which compromised pulmonary blood flow by application of proximal RPA clamp, thereby reducing flow to pulmonary circulation [Figure 2].

Discussion

Neurological dysfunction after cardiac surgery is a well-known entity. NIRS has emerged as the latest technology which helps clinicians to detect overt neurological injury after cardiopulmonary bypass (CPB). Recently, the role of NIRS has expanded from operating room to intensive care unit and cardiac catheterization laboratory as well. Cerebral NIRS monitoring in closed heart surgery has not been well researched and documented.[3]

NIRS technology is capable of continuous noninvasive monitoring of tissue oxygenation. It relies on relative transparency of biological tissues to near infrared (NIR) spectrum (700-900 mm wavelength) and differential absorption by chromophores including hemoglobin (Hb), myoglobin, and cytochrome aa_3.[4] NIR spectrum focuses on the amount of oxygenated and deoxygenated Hb levels within the underlying vasculature (veins, arteries, and capillaries) and represents a weighted tissue oxygen saturation measured from these three compartments. $rScO_2$ values are also influenced by several physiologic variables, including arterial oxygen saturation, systemic blood pressure, hematocrit, regional blood flow, regional blood volume, regional metabolic rate for oxygen, and compartmental arterial:venous ratio.[5]

Most of the previous studies have focused on NIRS' correlation with mixed venous oxygen saturation as well as postsurgical neurocognitive outcomes in on-pump cardiac surgeries. Very few case reports have documented the use of NIRS in closed heart surgeries.

Joshi *et al*. reported a case of the vascular ring where during construction of anastomosis between left common carotid artery and the divided anomalous left subclavian artery, an isolated drop in ipsilateral $rScO_2$ was noticed on clamping. Prompt corrective measures such as increasing FiO_2, inducing controlled hypercapnia, and short surgical

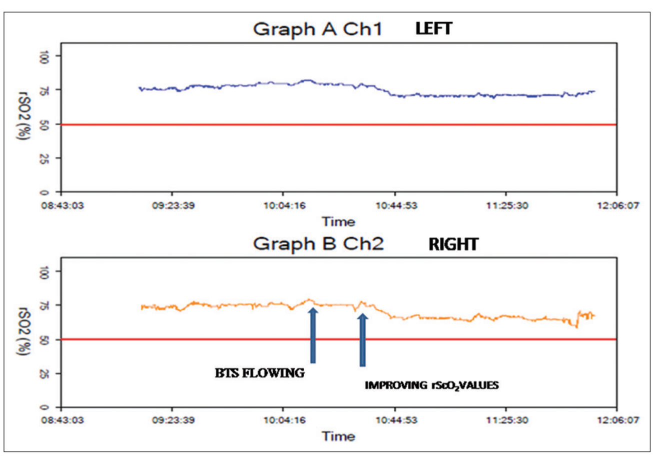

Figure 1: Case of pulmonary atresia for right modified Blalock Taussig shunt, drop in right $rScO_2$ after Blalock Taussig shunt started flowing. $rScO_2$: Regional cerebral oxygen saturation

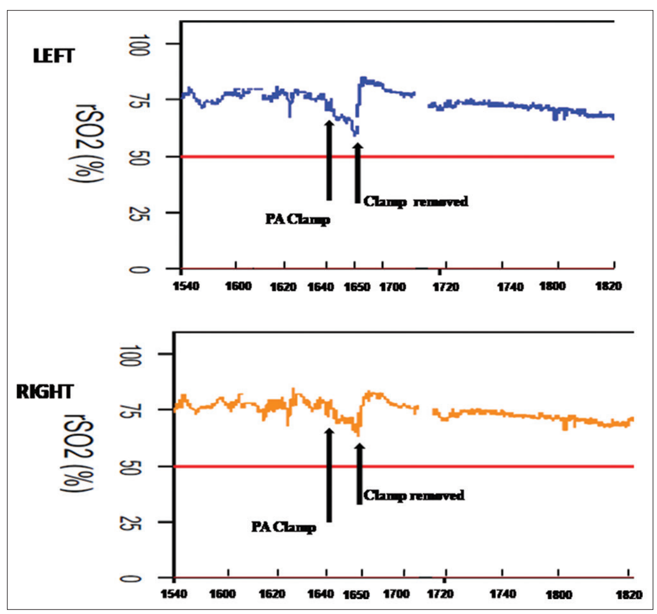

Figure 2: Drop in bilateral $rScO_2$ levels on clamping PA. $rScO_2$: Regional cerebral oxygen saturation, PA: Pulmonary artery

time along with a bolus of steroid led to avoidance of postoperative cerebral dysfunction.[6]

In another case report by Schwartz *et al*., RMBTS from innominate artery to pulmonary artery was constructed in a case of pulmonary atresia. On clamping right innominate artery, prompt fall in bilateral rScO2 was noted though only ipsilateral fall in rScO2 was expected. On discussion with surgical team, it was found that bilateral carotid arteries were arising from the right innominate artery and prompt clamp repositioning improved rScO2. Post-RMBTS, there was another episode of falling rScO2 with some amount of preferential flow to lungs by the shunt as well as functioning ductus and hence they planned to ligate the PDA.[7] In the first case, we found falling NIRS postfunctioning shunt due to preferential pulmonary flow. The second case highlights that the reduction of NIRS was the first value to drop when overall pulmonary circulation was diminished due to an anatomical variation of duct insertion site.

In surgical procedures conducted on CPB, a critical period of reduction in $rScO_2$ include cannulation for CPB, low flow CPB, rewarming and separation from CPB. In a series of pediatric cardiac surgical patients with NIRS monitoring, it alarmed 58% of "at-risk" events for brain injury. Patients who underwent any medical or surgical interventions on cerebral desaturation (change in rScO2) had significantly fewer neurologic complications (6% vs. 26%) as compared to those patients without any intervention.[8] Benefits of NIRS-based algorithms on the neurological outcomes in on-pump cardiac surgery has been controversial.[9] However in off-pump pediatric cardiac surgery, the role of NIRS has not been well researched.

We strongly propose the use of NIRS during the perioperative period of closed heart pediatric cardiac surgical procedures such as BTS, coarctation of the aorta and vascular rings. During BTS surgery, its use as a supportive monitor which can detect underflow and overflow across the shunt and also reveals any vascular anomalies left undetected by echocardiography. Real-time rSO_2 monitoring allows for detection and timely surgical intervention and can improve the outcome.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Andropoulos DB, Stayer SA, Diaz LK, Ramamoorthy C. Neurological monitoring for congenital heart surgery. Anesth Analg 2004;99:1365-75.
2. Ranucci M, Isgrò G, De la Torre T, Romitti F, Conti D, Carlucci C, *et al.* Near-infrared spectroscopy correlates with continuous superior vena cava oxygen saturation in pediatric cardiac surgery patients. Paediatr Anaesth 2008;18:1163-9.
3. Hirsch JC, Charpie JR, Gurney JG, Ohye RG. Role of near infrared spectroscopy in pediatric cardiac surgery. Prog Pediatr Cardiol 2010;29:93-6.
4. Sood BG, McLaughlin K, Cortez J. Near-infrared spectroscopy: Applications in neonates. Semin Fetal Neonatal Med 2015;20:164-72.
5. Ghosh A, Elwell C, Smith M. Review article: Cerebral near-infrared spectroscopy in adults: A work in progress. Anesth Analg 2012;115:1373-83.
6. Joshi R, Motto P, Horibe M, Mossad E. Monitoring cerebral oxygenation in pediatric patient undergoing surgery for vascular ring. Paediatr Anaesth 2006;16:178-81.
7. Schwartz JM, Vricella LA, Jeffries MA, Heitmiller ES. Cerebral oximetry guides treatment during blalock-taussig shunt procedure. J Cardiothorac Vasc Anesth 2008;22:95-7.
8. Austin EH 3rd, Edmonds HL Jr., Auden SM, Seremet V, Niznik G, Sehic A, *et al.* Benefit of neurophysiologic monitoring for pediatric cardiac surgery. J Thorac Cardiovasc Surg 1997;114:707-15, 717.
9. Serraino GF, Murphy GJ. Effects of cerebral near-infrared spectroscopy on the outcome of patients undergoing cardiac surgery: A systematic review of randomised trials. BMJ Open 2017;7:e016613.