Early detection of cerebral ischemia due to pericardium traction using cerebral oximetry in pediatric minimally invasive cardiac surgery: a case report

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Abstract

Background: Minimally invasive cardiac surgery (MICS) for simple congenital heart defects has become popular, and monitoring of regional cerebral oxygen saturation (rSO2) is crucial for preventing cerebral ischemia during pediatric MICS. We describe a pediatric case with a sudden decrease in rSO2 during MICS.

Case presentation: An 8-month-old male underwent minimally invasive ventricular septal defect closure. He developed a sudden decrease in rSO2 and right radial artery blood pressure (RRBP) without changes in other parameters following pericardium traction. The rSO2 and RRBP immediately recovered after removal of pericardium fixation. Obstruction of the right innominate artery secondary to the pericardium traction would have been responsible for it.

Conclusions: Pericardium traction, one of the common procedures during MICS, triggered rSO2 depression alerting us to the risk of cerebral ischemia. We should be aware that pericardium traction during MICS can lead to cerebral ischemia, which is preventable by cautious observation of the patient.

Keywords: Cerebral ischemia, Near-infrared spectroscopy, Pediatric, Minimally invasive cardiac surgery, Pericardium traction

Background

Over the last several decades, mortality following congenital heart surgery has been ameliorated because of innovative methodology and performance improvements in equipment used in cardiac surgery [1, 2]. Thus, for better quality of life after congenital heart surgery, it is important to prevent brain dysfunction caused by cerebral ischemia following iatrogenic vessel obstruction during cardiac surgery with cardiopulmonary bypass (CPB). Recently, minimally invasive cardiac surgery (MICS), which is characterized by small skin incision and minimal sternotomy or minithoracotomy, has become popular for use with simple congenital heart surgery and has contributed to good outcomes [3–5]. However, a smaller incision used in MICS makes it more difficult to recognize vessel obstruction leading to cerebral ischemia. Therefore, adequate intraoperative monitoring of brain oxygenation is essential for preventing perioperative cerebral ischemia [6, 7]. Presently, monitoring of regional cerebral oxygen saturation (rSO2) has assumed an important role in maintaining proper oxygenation of the brain during pediatric cardiac surgery [6, 7]. Here, we report a pediatric case in which a sudden decline in rSO2 alerted us to the possibility of cerebral ischemia due to arterial malperfusion following pericardium traction.

Case presentation

The patient was an 8-month-old male (height 65.7 cm; weight 7 kg) born through normal vaginal delivery weighing 2768 g. A heart murmur was audible, and the patient was diagnosed as having a perimembranous ventricular septal defect (VSD) with pulmonary hypertension due to a
left-to-right shunt 4 days after birth. Transthoracic echocardiography (TTE) showed that the defect passed from the perimembranous septum to the infundibular septum. The defect was 7.4–8.9 mm in diameter and was accompanied by mild tricuspid regurgitation (TR) and mitral regurgitation. The peak TR pressure gradient was 54 mmHg, and the left ventricle ejection fraction was 73%. The patient had no other congenital heart malformations. Although the patient was administered diuretics after diagnosis, he had poor weight gain after 5 months of age, secondary to heart failure. Therefore, the patient was scheduled for VSD closure with lower partial sternotomy.

Preoperative data were within normal ranges, with the exception of the concentration of hemoglobin (Hb) in blood ([Hb]) that was 10.2 g/dL. Upon arrival to the operating room, general anesthesia was induced with 5% sevoflurane in a mixture of 50% nitrous oxide and 50% oxygen. Following placement of an intravenous catheter, endotracheal intubation was facilitated with 70 μg fentanyl and 10 mg rocuronium. Anesthesia was maintained with 1–5% sevoflurane in the air, with concomitant fentanyl and rocuronium as required. During CPB, fentanyl, midazolam, and rocuronium were intravenously administered. Monitoring included electrocardiography and measurement of invasive right radial artery blood pressure (RRBP) and right femoral arterial blood pressure (RFBP), oxygen saturation of peripheral artery (SpO₂), values of regional cerebral oxygen saturation (rSO₂) measured with INVOS S100C, and nasopharyngeal temperature (Tₙaso). Some of these points beyond measurement limits are considered noise and were thus excluded.

Discussion

In this case, pericardium traction, one of the common procedures during MICS, triggered a decrease in rSO₂ that alerted us to the risk of cerebral ischemia. The change in rSO₂ was sufficient to cause us to speculate that cerebral ischemia might have occurred in the patient.

Recently, a smaller incision during median sternotomy has become an alternative technique during cardiac surgeries for simple congenital heart deformities, such as closure of VSD and atrial septum defects [3, 5]. The smaller incision in pediatric MICS forces the surgeon to pull up the pericardium more strongly to secure a field.
of view, which can subsequently deform the aorta or the branch (Fig. 2B), which would possibly lead to cerebral ischemia. Additionally, it is extremely difficult to visualize such a physical deformity of arteries by TEE in pediatric MICS. Hence, monitoring of cerebral saturation by near-infrared spectroscopy (NIRS) is becoming an alternative for avoiding such an unforeseen emergency. Some groups have reported that the decrease in rSO$_2$ was related to the surgical procedure in cardiac surgery [8, 9], whereas few reports have shown that simple traction of the pericardium can affect rSO$_2$ values as we experienced.

Accumulating studies show that the rSO$_2$ values measured by NIRS are trustworthy physiological indicators during pediatric cardiovascular surgeries [6, 7]. An interventional algorithm to prevent cerebral desaturation using NIRS has been introduced as a feasible strategy in clinical situations [7, 10, 11]. Following that algorithm, we concluded that arterial malperfusion was plausible because of the following observations: (1) the RRBP and rSO$_2$ values dropped simultaneously, (2) SpO$_2$ on the left hand remained unchanged, (3) the RFBP was maintained, (4) there was no apparent hemorrhage, (5) the CVP did not change, and (6) the patient’s heart rate and body temperature remained stable. Our decision to insert two artery catheters at the right radial artery and right femoral artery and monitor SpO$_2$ at the left hand and foot may have been excessive. However, we aimed to monitor the blood flow at all the extremities during pediatric MICS in order to be alert to any signs indicating obstruction of blood flow. It ultimately gave us more clues to understand what happened in this emergent situation and for future reference.

There are limitations to the use of NIRS devices for monitoring of cerebral saturation. In the present case, we chose the INVOS sensor that reflects a mixture of Hb saturation in venous, capillary, and arterial blood [7]. Alternatively, NIRO®, another device for monitoring cerebral saturation, can give us detailed information from each source [12]. Another issue to be considered is that we used an adult sensor to measure the rSO$_2$ value. Although standard values of rSO$_2$ vary depending on the type of sensor used [13, 14], they are enough to be trustworthy [6, 7]. In this case, we did not check bilateral brain saturation, but monitoring of RRBP and SpO$_2$ on the left hand provided us enough information. A carotid artery ultrasound and/or Transcranial Doppler ultrasound may be preferable for detecting cerebral malperfusions.

In conclusion, we experienced a pediatric case of MICS in which pericardium traction, one of the common procedures in MICS, caused a decrease in rSO$_2$, but we were able to prevent cerebral ischemia during the surgery with useful monitoring including rSO$_2$, arterial blood pressure, and SpO$_2$ at extremities. To achieve better quality of life after congenital heart surgery, we should be aware that pericardium traction during MICS can lead to cerebral ischemia that is preventable by cautious observation of the patient.

**Abbreviations**

CVP: Central venous pressure; ECG: Electrocardiography; EtCO$_2$: End-tidal carbon dioxide; FiO$_2$: Fraction of inspired oxygen; Hb: Hemoglobin; ICU: Intensive care unit; MICS: Minimally invasive cardiac surgery; NIRS: Near-infrared spectroscopy; RFBP: Right femoral arterial blood pressure; RRBP: Right radial arterial blood pressure; rSO$_2$: Regional cerebral oxygen saturation; SpO$_2$: Oxygen saturation of peripheral artery; T$_{rnx}$: Nasopharyngeal temperature; TR: Tricuspid regurgitation; VSD: Ventricular septal defect

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References
1. Jacobs JP, He X, Mayer JE Jr, Austin EH 3rd, Quintessenza JA, Karl TR, et al. Mortality trends in pediatric and congenital heart surgery: an analysis of The Society of Thoracic Surgeons Congenital Heart Surgery database. Ann Thorac Surg. 2016;102:1345–52.
2. Hirata Y, Hirahara N, Murakami A, Motomura N, Miyata H, Takamoto S. Current status of cardiovascular surgery in Japan 2013 and 2014: a report based on the Japan Cardiovascular Surgery Database. 2: Congenital heart surgery. Gen Thorac Cardiovasc Surg. 2018;66:4–7.
3. Bichell DP, Geva T, Bacha EA, Mayer JE, Jonas RA, del Nido PJ. Minimal access approach for the repair of atrial septal defect: the initial 135 patients. Ann Thorac Surg. 2000;70:115–8.
4. Iribarne A, Easterwood R, Chan EY, Yang J, Soni L, Russo MJ, et al. The golden age of minimally invasive cardiothoracic surgery: current and future perspectives. Future Cardiol. 2011;7:333–4.
5. Vida V, Zanotto L, Tessari C, Padalino MA, et al. Minimally invasive surgery for atrial septal defects: a 20-year experience at a single centre. Interact Cardiovasc Thorac Surg. 2019;28:961–7.
6. Dullenkopf A, Frey B, Bienerziger O, Gerber A, Weiss M. Measurement of cerebral oxygenation state in anaesthetized children using the INVOS 5100 cerebral oximeter. Paediatr Anaesth. 2003;13:384–91.
7. Murkin JM, Arango M. Near-infrared spectroscopy as an index of brain and tissue oxygenation. Br J Anaesth. 2009;103 (Suppl. 1):13–13.
8. Ito R, Takita K, Mizonoya K, Kida A, Morimoto Y. Use of near-infrared spectroscopy in combination with monitoring of external jugular vein pressure for early detection of cerebral ischemia by unintentional superior vena cava obstruction. J Cardiothorac Vasc Anesth. 2011;26:e27–8.
9. Rossi M, Tirotta CF, Lagueruela RG, Madril D. Diminished Blalock-Taussig shunt flow detected by cerebral oximetry. Paediatr Anaesth. 2007;17:72–4.
10. Denault A, Deschamps A, Murkin JM. A proposed algorithm for the intraoperative use of cerebral near-infrared spectroscopy. Cardiothorac Vasc Anesth. 2007;11:274–81.
11. Deschamps A, Hall R, Grocott H, Mazer CD, Choi PT, Turgeon AF, et al. Cerebral oximetry monitoring to maintain normal cerebral oxygen saturation during high-risk cardiac surgery. Anesthesiology. 2016;124:826–36.
12. Redlin M, Huebler M, Boettcher W, Kuppe H, Hetzer R, Habazettl H. How near-infrared spectroscopy differentiates between lower body ischemia due to arterial occlusion versus venous outflow obstruction. Ann Thorac Surg. 2011;91:1274–6.
13. Dix LM, Bel FV, Baerts W, Lemmers PM. Comparing near-infrared spectroscopy devices and their sensors for monitoring regional cerebral oxygen saturation in the neonate. Pediatric Res. 2013;74:557–63.
14. Yagi Y, Yamamoto M, Sato H, Mori T, Morimoto Y, Oyasu T, et al. Changes of cerebral oxygenation in sequential Glenn and Fontan procedures in the same children. Pediatr Cardiol. 2017;38:1215–9.