



[ Case Report ]

## Near infrared spectroscopic assessment of cerebral blood flow after bidirectional superior cavopulmonary anastomosis

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### Abstract

**Bidirectional superior cavopulmonary anastomosis (BCPA) is now widely accepted as palliative surgery for congenital heart diseases such as hypoplastic left heart syndrome. Although hyperventilation is useful for decreasing pulmonary vessel resistance, reducing cerebral blood flow (CBF) may lead to low oxygenation after BCPA. However, Hoskote and Li concluded that moderate hypercapnia, which increases CBF, improved arterial oxygenation, reduced oxygen consumption and arterial lactate levels, thus improving overall oxygen transport in children after BCPA. We report here the use of near infrared spectroscopy (NIRS) in our pediatric intensive care unit as a routine and useful bedside method of monitoring CBF after BCPA. We found clearly that hypercapnia increased the tissue oxygenation index on NIRS and improved oxygenation after BCPA. This hyperventilation strategy may have life-saving potential for some patients after BCPA, and its use in conjunction with NIRS bedside monitoring should be promoted in Japan.**

**Key words:** Pediatric, Glenn, Bidirectional Glenn, Cerebral blood flow, Pulmonary blood flow

### I . Introduction

Bidirectional superior cavopulmonary anastomosis (BCPA), one of the surgical strategies in the so-called Glenn procedure, is now widely accepted as palliative surgery for congenital heart diseases[1]. It is also part of the surgical treatment strategy for cases of single-ventricle physiology such as hypoplastic left heart syndrome[2]. In this procedure, the superior vena cava (SVC) is connected to the pulmonary artery (PA) to

increase PA blood flow, and the success of this palliative procedure depends on adequate PA blood flow and low pulmonary vessel resistance (PVR) [3-5].

In general, to decrease PVR, we usually perform hyperventilation to promote blood alkalosis or give inhaled nitric oxide (iNO). However, hyperventilation and/or iNO have been shown to be ineffective and do not improve oxygenation in the absence of intrapulmonary shunt[6,7]. This maneuver leads to low arterial partial pressure of carbon dioxide (PaCO<sub>2</sub>) and results in decreased cerebral blood flow (CBF). In BCPA physiology, it results in decreasing the blood flow returning from the brain through the superior vena cava to the PA[8-10].

With this physiology in mind, we reviewed several

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studies including that of Hoskote and Li and concluded that moderate hypercapnia, which increases CBF, improved arterial oxygenation and reduced oxygen consumption and arterial lactate levels, thus improving overall oxygen transport in children after BCPA [11-13].

In the current study, we estimated the increase in CBF using several devices including near infrared spectroscopy (NIRS), which is widely used for non-invasive and continuous brain oxygenation monitoring in neurological critical care including pediatric cardiac surgery patients [14-17]. NIRS was originally described as a novel device for monitoring changes in the intracranial chromopher levels of oxyhemoglobin ( $O_2Hb$ ) and deoxygenated hemoglobin (HHb). Excellent correlation between NIRS data and cerebrovascular phenomena, including intracranial hemorrhage, vasospasms, and increased intracranial pressure, has been reported.

We report here the use of NIRS in our ICU a routine and useful bedside method of monitoring CBF after BCPA.

## II. Case

A 1-year-old boy diagnosed as atrioventricular septum defect and hypoplastic right ventricle underwent BCPA. He admitted to pediatric intensive care unit (PICU) with arterial, central venous, and Glenn pressure line in place as usual. Frequent measurements of blood gas were taken through his arterial line by bedside pediatric intensivists within the usual post-operative care fashion.

We started NIRS assessment soon after the PICU admission. NIRS was used for the routine bedside monitoring, and NIRO-200™ (Hamamatsu Photonics Co., Japan) was used. The optodes were placed on the forehead of the patient's frontal scalp, with the distance between them fixed at 4 to 5 cm. Signal strength was adjusted with or without a signal attenuator. The differential pathlength factor (DPF) was fixed at 3.85, the usual setting for children. The tissue oxygenation index (TOI) was measured continuously by the device (Fig. 1 (a, b)). The TOI and arterial blood gas values

including arterial partial pressure of oxygen ( $PaO_2$ ) and carbon dioxide ( $PaCO_2$ ) were measured and recorded simultaneously.

Soon after the admission to PICU, he presented mild deterioration of oxygenation ( $PaO_2$  decreased below 40's mmHg). Since he was still deeply sedated and paralyzed, we started mild hypoventilation to increase

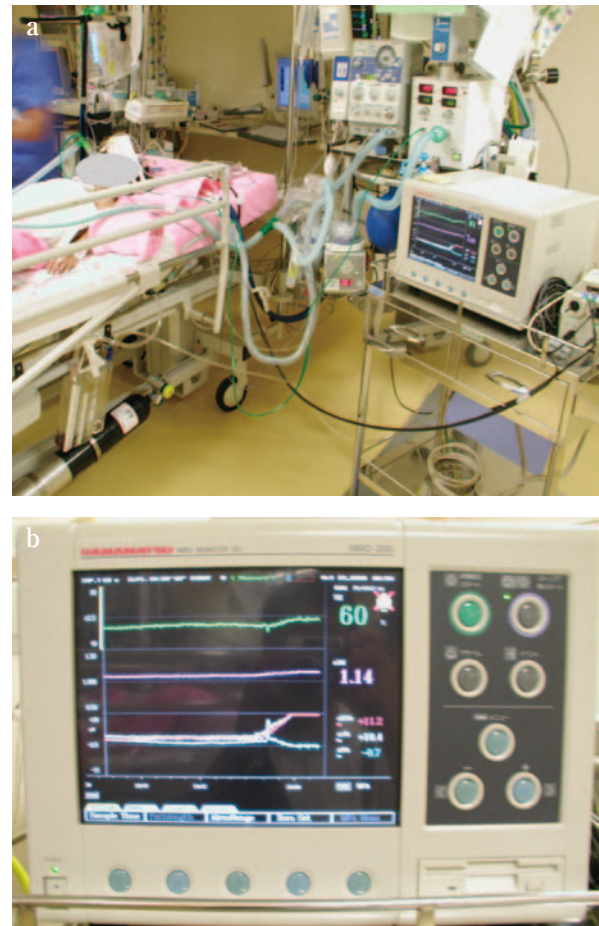


Fig. 1

- (a) NIRO-200TM at bedside  
 (b) Monitor screen indicating change of TOI

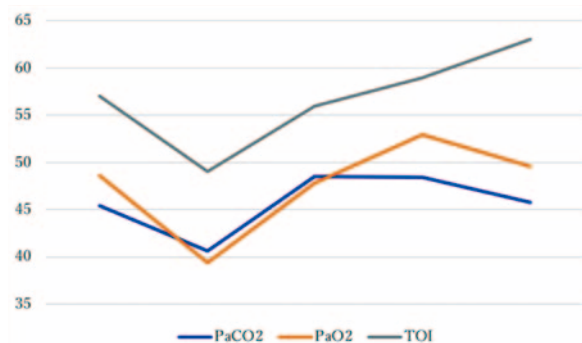


Fig. 2

Table 1 Serial change and correlation between TOI measured by NIRO-200<sup>TM</sup> and PaCO<sub>2</sub>/PaO<sub>2</sub> value analyzed from blood gas sample

Time from T0 (minutes)	pH	PaCO <sub>2</sub>	PaO <sub>2</sub>	TOI
0	7.323	45.4	48.6	57
10	7.419	40.6	39.4	49
15	7.363	48.5	47.8	56
70	7.353	48.4	52.9	59
110	7.355	45.8	49.6	63

PaCO<sub>2</sub>. As a result, his PaCO<sub>2</sub> increased to around 50's mmHg, and PaO<sub>2</sub> increased above 50's mmHg. Additionally, his TOI measured by NIRS increased at the same time (Fig. 2, Table 1). Correlations between TOI and PaCO<sub>2</sub>/PaO<sub>2</sub> were clearly indicated. Hypoventilation improved oxygenation, and TOI was simultaneously increased suggesting increased CBF.

### III. Discussion

Hoskote and Li were the first to demonstrate precisely that hypercapnia with respiratory acidosis reduces systemic oxygen consumption and arterial lactate levels in paralyzed and ventilated children in the immediate post BCPA period[12,13]. In these studies, they demonstrated that increasing PaCO<sub>2</sub> from 35 to 55 mm Hg with respiratory acidosis improved systemic oxygenation, systemic blood flow, cerebral blood flow, and pulmonary blood flow and decreased systemic vascular resistance without increasing pulmonary vascular resistance after a BCPA[12,13].

These changes were marked when PaCO<sub>2</sub> increased from 35 to 45 mm Hg. Increasing the PaCO<sub>2</sub> from 45 to 55 mm Hg augmented PaO<sub>2</sub> and maintained favorable pulmonary, systemic and cerebral blood flows without increasing pulmonary vascular resistance. Furthermore, decreasing PaCO<sub>2</sub> from 55 to 40 mm Hg, by withdrawing exogenous carbon dioxide, caused the return of all parameters towards baseline[12,13].

The finding of a hypercapnia-related reduction in systemic oxygen consumption is unique and may have important implications in the management of patients after BCPA. These results may have important implications in the management of the hypoxic child

after the BCPA, and a permissive hypercapnic strategy may improve the postoperative course, particularly in young infants. It is equally evident that a PaCO<sub>2</sub> lower than 45 mm Hg has a deleterious effect on oxygenation and hemodynamics and may be counterproductive after the BCPA[6]. Although this approach was already widespread internationally over 10 years ago, it is still not widely accepted in Japan.

In Hoskote and Li's study, NIRS using the older and complicated NIRO-300<sup>TM</sup> (Hamamatsu Photonics Co., Japan) provided background data and showed similar results to those we described in this article[16]. The current study is the first to show that NIRS indicated a clear correlation between TOI and PaCO<sub>2</sub> as well as demonstrating the convenience of NIRS as a routine, bedside method of monitoring CBF by NIRO-200<sup>TM</sup>. By using NIRO-200<sup>TM</sup>, we were able to infer easily that increased CBF caused by hypoventilation resulted in increased SVC and PA flow and improved oxygenation.

In general, after BCPA, early spontaneous respiration and extubation are the mainstay of postoperative management in the PICU. However, in some cases a high PVR and/or low PA index might preclude early extubation and cause low oxygenation. In such cases, the hypoventilation strategy may prove life-saving. This rescue option in conjunction with NIRS use for routine bedside monitoring should be promoted in Japan.

### Contributors

NS, OS, and NN cared for the patient and contributed to writing of the report. Consent to publication was obtained from the family. Publication was approved by the Institutional Review Board of both National Center of Child Health and Development and Tokyo Metropolitan Children's Medical Center. Authors thank Mr. James Robert Valera for his assistance with editing the manuscript.

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