# Near-infrared spectroscopy for monitoring leg perfusion during minimally invasive surgery for patients with congenital heart defects

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Regional oxygen saturation measured by means of near-infrared spectroscopy (NIRS) have been used as potential surrogate of cerebral and somatic mixed venous oxygen saturation and has been suggested as a noninvasive tool to continuously monitor and detect states of low body perfusion.[1-5] We sought to evaluate the safety of peripheral arterial cannulation by using NIRS in patients undergoing minimally invasive heart surgery for correcting simple congenital heart diseases, focusing on patients with a body weight less than 30 kg.

## PATIENTS

We evaluated 50 patients who underwent remote cardiopulmonary bypass (CPB) by femoral cannulation for the correction of simple congenital heart defects between January 2009 and May 2011.[1,2] The distal femoral artery had not been occluded in our patients and a distal selective arterial perfusion was not used.

NIRS (using the INVOS 5100 cerebral oximeter; Somanetics Corp, Troy, Mich) was used to continuously monitor any variation of oxygen saturation during the extracorporeal perfusion on both lower extremities (NIRS sensors are positioned on the anterior side). After the operation, creatine kinase (CK) and myoglobin plasmatic levels were evaluated, together with the CPB time and the type of surgical approach.

Median age at surgery was 17.9 years (range, 6-56 years) and median body weight was 48 kg (range, 18-91 kg). Primary surgical maneuvers included (1) ostium secundum atrial septal closure (n = 40), (2) repair of partial anomalous pulmonary venous return (n = 8), and (3) discrete subaortic membrane resection (n = 2). The surgical approach was through a right anterior minithoracotomy in 35 patients, a right posterior minithoracotomy in 13, and a ministernotomy in 2. Femoral vessels were cannulated through a purse-string suture in all. During CPB, at full flows, median NIRS values dropped from 81 (range, 72-88) to 50.5 (range, 20-71; $P = .001$) in the cannulated leg whereas it remained stable on the contralateral leg; this was found related to the body weight of the patients (Table 1). No patient required conversion to central cannulation or the additional cannulation of the contralateral leg for flow reasons, and we did not need to reconstruct the femoral vessels after decannulation. We did not record any sign of perioperative leg ischemia at the end of surgery, and postoperative vascular ultrasound revealed a normal perfusion of the cannulated extremity without evidence of stenosis in all. Peak median postoperative CK levels were 680 U/L (range, 291-28,736 U/L), 2 (4%) patients having a level greater than 4000 U/L. The peak median postoperative plasmatic myoglobin level was 380 U/L (range, 84-6430 U/L), with 4 (8%) patients having a level greater than 1000 U/L (Tables 1 and 2). A forward linear regression analysis correlates the increase of plasmatic CK and myoglobin level to CPB time ($P < .0001$). There were no clinical side effects from the increased CK of myoglobin. It is of note that different surgical approaches required different perfusion times, which were longer in patients who required a posterior right minithoracotomy (Table 2). On that basis, we determined that a remote CPB time longer than 80 minutes would explain

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**TABLE 1. Somatic NIRS values on the cannulated leg and perfusion data according to patient's body weight (n = 50 patients)**

| | BW 18-30 kg (n = 11) | BW 31-50 kg (n = 16) | BW > 51 kg (n = 23) | P* |
|---|---|---|---|---|
| Median NIRS value before cannulation (range) | 81 (76-88) | 81.5 (78-87) | 79 (72-88) | .1 |
| Median NIRS value during CPBP (range) | 34 (20-47) | 43.5 (32-67) | 55 (45-71) | **<.001** |
| Median NIRS value after decannulation (range) | 83 (74-86) | 80.5 (75-86) | 77 (72-86) | .1 |
| Median CPB time (range) | 45 (21-228) | 41.5 (23-170) | 58 (31-160) | .7 |
| Peak CK plasmatic level in U/L (range) | 682 (413-28,736) | 1263 (446-7,072) | 666 (291-2,110) | .4 |
| Peak myoglobin plasmatic level in mg/dL (range) | 368 (84-6,430) | 722 (480-1,899) | 254 (87-977) | .7 |

*NIRS,* Near-infrared spectroscopy; *BW,* body weight; *CPB,* cardiopulmonary bypass; *CK,* creatine kinase. *Kruskal-Wallis test.

**TABLE 2. Somatic NIRS values on the cannulated leg and perfusion data according to the type of surgical approach (n = 50 patients)**

| | Ministernotomy (n = 2) | Anterior right MT (n = 35) | Posterior right MT (n = 13) | *P** |
|---|---|---|---|---|
| Median NIRS value during CPB (range) | 45 (34-56) | 50 (20-71) | 51 (34-67) | .7 |
| Median body weight (range) | 34 (26-42) | 47 (18-81) | 50 (27-91) | .3 |
| Median CPB time (range) | 53 (45-62) | 41 (21-141) | 108 (73-228) | **<.0001** |
| Peak CK plasmatic level in U/l (range) | 555 (480-630) | 556 (291-1,444) | 2046 (975-28,736) | **.0002** |
| Peak myoglobin plasmatic level in mg/dl (range) | 341 (270-412) | 368 (84-621) | 1561 (284-6,430) | **.01** |

*NIRS,* Near-infrared spectroscopy; *MT,* minithoracotomy; *CPB,* cardiopulmonary bypass; *CK,* creatine kinase. *Kruskal-Wallis test.

a significant increase of both CK and myoglobin plasmatic levels in patients with a body weight of less than 30 kg where the NIRS values on the cannulated leg reach levels more than 30.

## DISCUSSION

A prolonged period of limb ischemia in patients undergoing minimally invasive operations, especially when the femoral artery has been clamp occluded, has the potential to cause ischemic complications.[3] The use of NIRS to monitor the lower extremities in these patients was a valid and reproducible method for assessing tissue oxygenation of the perfused leg, immediately showing signs of leg ischemia if insufficient leg perfusion is provided.[4,5]

According to our results, there was a significant drop of the tissue oxygenation (as decreased NIRS values) after femoral artery cannulation and CPB, which was found in direct correlation with the body weight of the patient. We did not have any case of peripheral leg ischemia; however, we found increased postoperative levels of CK and myoglobin levels that were directly correlated to the time of distal leg perfusion. On the contrary, no association was found between the CK and myoglobin level and the NIRS values during CPB or patient's body weight.

We speculate that the remote CPB with direct femoral artery cannulation can be safely used in patients with a body weight less than 30 kg without increased operative morbidity or complications. The prolonged CPB time is associated with plasmatic elevation of CK and myoglobin levels, especially in patients with a low body weight (<30 kg) and with very low NIRS values (<30) on the cannulated leg during extracorporeal perfusion. Inasmuch as different surgical approaches required different CPB times and consequently a longer distal leg perfusion time (ie, right posterior minithoracotomy), we intend to change our minimally invasive policy by adding selective distal leg perfusion when prolonged CPB time is expected.

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