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SHORT COMMUNICATION

The usefulness of near-infrared spectroscopy in the anesthetic management of endovascular aortic aneurysm repair

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Abstract Near-infrared spectroscopy (NIRS) may be a useful method for monitoring the regional oxygen saturation (rSO_2) of the lower extremity during endovascular aortic repair. Eighteen patients with thoracic descending and/or abdominal aortic aneurysm were enrolled in this study. NIRS probes were placed bilaterally on the calves. Muscular rSO_2 ($mrSO_2$) was monitored every 30 s throughout the operation. In the leg in which the femoral artery was clamped, $mrSO_2$ values were selected at 3 or 4 points–just before clamping (control value), 30 min after clamping, 10 min after the first declamping, and 10 min after the second declamping following repair of the femoral artery, if necessary. In all patients, $mrSO_2$ decreased significantly during clamping, from 64 ± 11 % (mean $\pm$ SD) of the control value to 32 ± 15 %. After declamping, $mrSO_2$ recovered to 69 ± 14 % of the control value in 16 patients. In the 2 other patients, however, $mrSO_2$ did not recover after the first declamping, because of femoral artery dissection. After additional repair, $mrSO_2$ recovered quickly to the control value. These data suggested NIRS may objectively and quantitatively reflect oxygenation of the lower extremities, and may indicate an ischemic event that needs additional repair during endovascular aortic repair.

Keywords Near-infrared spectroscopy · Perfusion · Lower extremity · Aortic aneurysm · Endovascular aortic repair

Near-infrared spectroscopy (NIRS) is a noninvasive monitoring method used to measure tissue oxygen saturation. It radiates near infrared light passing through the skin and skull to identify hemoglobin and oxygenated hemoglobin molecules within red blood cells, and measures the relative amounts of each to determine their degree of oxygenation. Previous reports have found that NIRS might be a useful noninvasive monitor of cerebral regional oxygen saturation (rSO_2) indicating the severity of cardiopulmonary-cerebral dysfunction and postoperative mortality and morbidity. In addition, it has been reported that decreased cerebral rSO_2 indicated inadequate cerebral perfusion and critical states during cardiovascular surgery [1–4]. Further, several reports have shown that the rSO_2 or oxyhemoglobin of the trunk or extremities reflected the perfusion of those areas during pediatric and adult cardiovascular surgeries and postoperative rehabilitation [5–13].

For the treatment of abdominal aortic aneurysm (AAA), although open repair surgery has been performed traditionally, endovascular aortic repair (EVAR) is becoming adopted as an alternative method. In both methods, lower-limb ischemia, graft thrombosis, dissection, and access site injury have been reported previously and the occurrence rates were about 0.9–17 % [14–19]. Doppler sonography has been used to assess peripheral vascular perfusion, but this method is generally subjective and qualitative [20, 21]. By contrast, previous studies have shown that NIRS values well reflected the local oxygenation status of the buttock and lower extremities during laparotomic AAA surgery and endoscopic cardiac surgery and during the postoperative period

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[7–13]. But there are no reports about rSO_2 in the lower extremity during EVAR. The purpose of this study was to clarify the NIRS values in normal and ischemic states, and to determine whether NIRS could be used for monitoring changes of rSO_2 in the lower extremity, and whether NIRS could indicate leg ischemia upon stenosis, thrombosis, dissection, and access site injury during EVAR.

This study was approved by the institutional review board of Iwate Medical University Memorial Heart Center (Iwate prefecture, Japan), and written informed consent was obtained from each enrolled patient. Eighteen patients with thoracic descending aneurism and/or AAA were enrolled in this study. They underwent EVAR under general anesthesia at Iwate Medical University Memorial Heart Center between December 2008 and July 2010.

Except for patients in whom there were contraindications, an epidural catheter was inserted in the Th12/L1 intervertebral space on the day prior to surgery. No premedication was given on the day of surgery. Infusion of acetate Ringer's solution into the forearm vein was started at a rate of 100 ml/h 2 h before surgery. Electrocardiogram, radial arterial blood pressure, and percutaneous pulse oximetry were monitored during anesthesia. After 6 l/min of oxygen inhalation was started, general anesthesia was induced with the intravenous administration of 0.1 mg/kg midazolam, 0.6 mg/kg rocuronium, 5 μg/kg fentanyl, and an additional 1–1.5 mg/kg propofol if needed. After the trachea was intubated, inhalation of 0.5–1.0 % of sevoflurane, continuous intravenous infusion of 0.5–1.0 mg/kg/h of propofol, and 0.10–0.30 μg/kg/min of remifentanil were started for the maintenance of anesthesia. A central venous catheter was inserted via the right jugular vein after tracheal intubation. And we intermittently administered ephedrine, phenylephrine, or nicardipine so that patient's systolic arterial blood pressure was maintained between 80 and 100 mmHg. In patients with epidural anesthesia, 0.1 ml/kg of 1 % lidocaine was administered via the catheter every hour. Continuous intravenous infusion of 2–6 mg/h of nicorandil was performed for patients who had ischemic coronary disease.

An INVOS 5100c spectroscope (Somanetics, Troy, MI, USA) was used for the NIRS. NIRS probes were placed bilaterally on the calves and shielded from light to avoid artifacts. Muscular rSO_2 ($mrSO_2$) was monitored every 30 s throughout the operation. In the leg in which the femoral artery was clamped, $mrSO_2$ values were selected at 3 or 4 points—just before clamping (pre-clamping/control value), 30 min after clamping, 10 min after the first declamping, and 10 min after the second declamping following repair of the femoral artery, if needed. In this study, reduction of rSO_2 was defined as a 20 % relative decrease from the pre-clamping (control) value, and recovery was defined as 80 % or more of the pre-clamping rSO_2 value [4].

Data are presented as means ± standard deviation (SD). To examine the distribution and the equality of variance, the Kolmogorov–Smirnov test and Levene test were used. Statistical comparisons were performed using one-way repeated measures analysis of variance and the *t*-test with Bonferroni correction. Differences with a p value of less than 0.05 were considered significant. For statistical analyses, IBM SPSS Statistics Version 19 (SPSS, IBM, Armonk, NY, USA) was used.

The values for the patients' age, height, weight, and operation time were 76 ± 7 years, 161 ± 10 cm, 59 ± 11 kg, and 167 ± 98 min, respectively. The aneurysm lesions were as follows: 10 in the abdominal aorta, 6 in the thoracic descending aorta, and 2 in both. In all cases, $mrSO_2$ decreased significantly during clamping of the femoral artery, from 64 ± 11 % of the pre-clamping value to 32 ± 15 %. After declamping, $mrSO_2$ recovered to 69 ± 14 % of the pre-clamping value in 16 patients. However, in the 2 remaining patients, a 79-year-old woman and an 84-year-old man, who both underwent EVAR for a thoracic descending aortic aneurysm, the $mrSO_2$ did not recover after the first declamping (Table 1). Immediate angiography showed severe stenosis of the femoral artery because of an intimal flap that had developed owing to femoral artery dissection, and surgeons needed to repair the femoral artery. The $mrSO_2$ change in one of the ischemic patients is shown in Fig. 1. After additional repair, the $mrSO_2$ recovered quickly to the control value in both patients. In all patients, the $mrSO_2$ values during clamping were significantly lower than those at the pre-clamping and post-declamping points ($p < 0.001$ for both comparisons). In 11 of the above 16 patients (68.8 %), the $mrSO_2$ values recovered to more than the control value. All patients were checked for signs of leg ischemia, with various examinations, carried out repeatedly during the postoperative period, such as palpation and Doppler sonography for the dorsalis pedis arteries, and observations of the skin color, temperature, and local pain, and we found no leg ischemia in any patients.

The present study was designed to investigate whether it was possible to assess perfusion and oxygenation in local tissues with NIRS. There have been many recent reports of

Table 1 The values of $mrSO_2$ (%) at each time point in the 2 dissection cases

	Pre-clamping	During clamping	Post-1st declamping	Post-2nd declamping
Case 1	61	15	21	70
Case 2	46	22	24	55

$mrSO_2$ muscular regional oxygen saturation, *dissection cases* data of patients who showed no $mrSO_2$ recovery after the 1st declamping and needed additional repair to the femoral artery

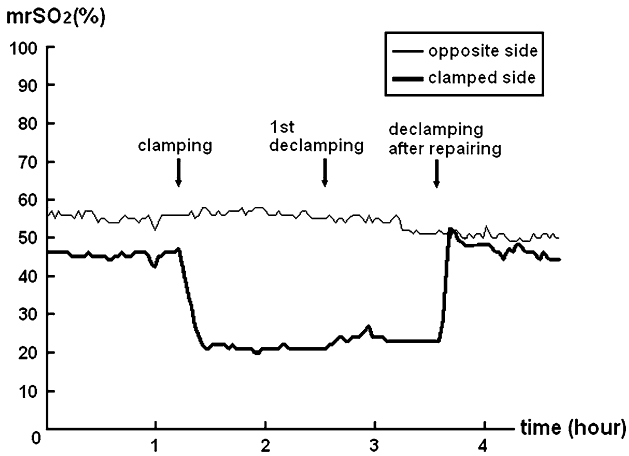

Fig. 1 Time series of changes in muscular regional oxygen saturation (*$mrSO_2$*) in one of the patients with dissection. No recovery of $mrSO_2$ was observed at post-1st declamping. After surgical repair, $mrSO_2$ quickly recovered to more than the control value

NIRS as a method of tissue oxygenation monitoring. Preoperative cerebral rSO_2 has been reported to indicate the severity of cardiopulmonary dysfunction and postoperative morbidity and mortality in cardiac surgery [1]. Perioperative cerebral rSO_2 has been reported to have a fair correlation with superior vena cava venous oxygen saturation and to have provided good accuracy in detecting cerebral ischemia and adverse neurological outcomes in surgery for congenital heart disease and cerebrovascular disease [2–4]. Moreover, it has been reported in some studies that it is possible to use NIRS to monitor lower torso, thoracodorsal, pelvic, buttock, and lower-leg oxygenation. In these reports, extra-cerebral rSO_2 was successfully used to monitor somatic, pelvic, or leg oxygenation, and so was useful for the diagnosis or evaluation of inappropriate cross-clamping positions, impaired leg perfusion, and postoperative buttock claudication [5–13]. However, we could not find any statements about NIRS monitoring during EVAR. In our study, all patients without intraoperative ischemic events at surgical sites showed similar changes in $mrSO_2$, the value of which decreased slowly during arterial clamping and recovered quickly after declamping. In 11 of 16 patients, the $mrSO_2$ of the declamped leg recovered to more than the control value. This trend matches the hyperoxygenation phenomenon after tourniquet deflation, reported previously [22]. Thus, the results of the present study suggested that NIRS could reflect local tissue perfusion and oxygenation status.

Furthermore, NIRS warned us of lower-extremity ischemia after reperfusion caused by femoral artery dissection in 2 operations. Rupture, anastomotic aneurysm, pseudoaneurysm, stenosis, occlusions, thrombosis, arterial dissection, graft kinking, hematoma, infection, and lymphocele have been reported as perioperative complications during aortic aneurysm repair, with incidences ranging from 0.9 to 17 % [14–19]. When only intraoperative events were considered, incidences of 3.5 % for intraoperative limb ischemia and 4-38 % for arterial dissection or injury at the catheter access site have been reported [16, 18, 19]. It has also been reported that clinically undetectable (but hemodynamically significant) intramural flaps were observed in 14 % of femoral arteries on intraoperative arterial duplex scans [18]. These complications with ischemic changes might be detected by NIRS.

Our study has several limitations. Firstly, sampling the venous blood was not involved in this study design. As previously reported, ischemia caused changes in blood pH and lactate concentration [12]. These variables might have been useful for further analysis and assessment. Secondly, we observed only 2 cases of femoral artery dissection. Further experiences will be needed for stronger evidence. And, lastly, it was possible that we missed “false-negative” changes of NIRS values. Although perfusion status in the legs in our patients was repeatedly examined with other methods during the postoperative period, no subsequent study such as postoperative angiography was performed.

In conclusion, NIRS reflected the oxygenation of the lower extremity both objectively and quantitatively during EVAR. Using this monitoring method, it is possible to detect local tissue ischemia caused not only by arterial clamping, but also by arterial stenosis, occlusion, or dissection; thus, it is possible to provide appropriate treatment.

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