Near-infrared Spectroscopy Monitoring of the Collateral Network Prior to, During, and After Thoracoabdominal Aortic Repair: A Pilot Study

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WHAT THIS PAPER ADDS

This study evaluates, for the first, time non-invasive monitoring of the collateral network oxygenation by means of near-infrared spectroscopy prior to, during, and after thoracoabdominal aortic repair in a clinical series. Although shown to be a feasible monitoring method for routine utilization in a clinical setting, specific studies are needed before it can be used to facilitate guidance in peri- and intraoperative perfusion management.

Objective: The aim of this study was to evaluate the feasibility of non-invasive monitoring of the paraspinous collateral network (CN) oxygenation prior to, during, and after thoracoabdominal aortic repair in a clinical series.
Methods: Near-infrared spectroscopy optodes were positioned bilaterally—over the thoracic and lumbar paraspinous vasculature—to transcutaneously monitor muscle oxygenation of the CN in 20 patients (age: 66 ± 10 years; men = 11) between September 2010 and April 2012; 15 had open thoracoabdominal aortic repair (Crawford II and III), three had thoracic endovascular aortic repair (TEVAR; Crawford I), and two had a hybrid repair (Crawford II). CN oxygenation was continuously recorded until 48 hours postoperatively.
Results: Hospital mortality was 5% ($n = 1$), 15% suffered ischemic spinal cord injury (SCI). Mean thoracic CN oxygenation saturation was 75.5 ± 8% prior to anesthesia (=baseline) without significant variations throughout the procedure (during non-pulsatile cooling on cardiopulmonary bypass and with aortic cross-clamping; range = 70.6—79.5%). Lumbar CN oxygenation (LbS) dropped significantly after proximal aortic cross-clamping to a minimum after 11.7 ± 4 minutes (74 ± 13% of baseline), but fully recovered after restoration of pulsatile flow to 98.5% of baseline. During TEVAR, stent-graft deployment did not significantly affect LbS. Three patients developed relevant SCI (paraplegia $n = 1$/paraparesis $n = 2$). In these patients LbS reduction after aortic cross-clamping was significantly lower compared with patients who did not experience SCI ($p = .041$).
Conclusions: Non-invasive monitoring of CN oxygenation prior to, during, and after thoracoabdominal aortic repair is feasible. Lumbar CN oxygenation levels directly respond to compromise of aortic blood circulation.

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INTRODUCTION

Paraplegia remains the most devastating complication after repair of extensive descending thoracic aneurysms (DTA) and thoracoabdominal aortic aneurysms (TAAA).[1] The maintenance of adequate spinal cord oxygenation is critical to the success of open and endovascular repair of TAAAs to prevent spinal cord ischemia when blood flow to the spinal cord is impaired (e.g., by segmental artery occlusion or aortic cross-clamping). Monitoring of spinal cord function using motor evoked potentials (MEP) or somatosensory evoked potentials (SSEP) is widely accepted in the assessment of intraoperative spinal cord viability during aortic procedures, but it requires significant technical effort and invasiveness.[2,3] It has been shown that paraplegia may be reduced by sustaining a *supranormal* mean arterial pressure peri-operatively and by routine use of cerebral fluid (CSF) drainage.[4–7] Despite these and other strategies and technical improvements spinal cord ischemic injury remains significant with an incidence of 5—11% in contemporary series.[8]

The recent introduction of "the collateral network (CN) concept" by Etz et al.[9]—based on experimental and clinical data—demonstrates that blood supply to the spinal cord is provided by a rich network of paraspinous arterial collaterals enabling sufficient blood flow in chronic ischemia or acutely after extensive sacrifice of segmental arteries.

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Monitoring of spinal cord integrity, however, remains challenging and difficult to interpret. According to the CN concept, blood supply to the paraspinous vasculature correlates with spinal cord blood supply. Critical spinal cord ischemia can occur not only during extensive thoracoabdominal aortic repair, but can also be delayed owing to inadequate postoperative spinal cord perfusion.[10,11] It is therefore of great importance to measure the adequacy of spinal cord blood supply intra- and postoperatively.

We theorize that oxygenation of the paraspinous CN—which is fed by the segmental arteries, as well as the spinal cord—may directly correlate with spinal cord blood supply.

Near-infrared spectroscopy has been shown to effectively monitor cerebral oxygen saturation during cardiopulmonary bypass and selective cerebral perfusion.[12–15] Analogous to this, we used conventional near-infrared spectroscopy (NIRS) optodes to monitor tissue oxygenation of the thoracic and lumbar paraspinous muscles—hence the paraspinous CN—to provide real-time, non-invasive spinal cord monitoring, potentially indicating pending spinal cord ischemia.

With the results of this study we prove feasibility of this new non-invasive monitoring tool in clinical practice.

MATERIALS AND METHODS

Between September 2010 and April 2012 a total of 73 patients was treated for thoracoabdominal aortic pathologies (32 open aortic repair and 41 stent interventions). Twenty patients were included in this study (age: 66 ± 10 years; men = 11): fifteen who received open thoracic or thoracoabdominal aortic (TAAA) repair (Crawford II + III), three thoracic endovascular aortic repair (TEVAR) (Crawford I), and two who received hybrid repair (second stage, Crawford II). All patients were enrolled non-consecutively depending on the presence of trained research personnel for documentation on site. Each enrolled patient is reported on; no patient was excluded in the course of this study. During open TAAA repair cooling to a mean rectal temperature of 31 ± 3 °C (median: 32 °C) was performed. In Crawford II aneurysms, visceral perfusion via a balloon catheter was utilized after distal aortic clamping. CSF drainage was only used during and after open TAAA repair to maintain an intrathecal pressure <12 cmH_2O or below opening pressure. The CSF catheter was removed 72 hours postoperatively.

NIRS optodes were positioned bilaterally—above the upper thoracic (T5—T7) and lumbar (L1—L3) paraspinous vasculature of the CN (Fig. 1, left)—for non-invasive transcutaneous monitoring of regional tissue (muscle) oxygen saturation of haemoglobin, as indicated on the NIRS device interface (Fig. 1, upper right). CN oxygenation was continuously recorded—prior to, during, and after—TAAA repair until 48 hours postoperatively (Fig. 2). Arterial blood pressure was measured at all times invasively via a catheter placed in the radial and femoral artery. Arterial blood pressure is expressed in mmHg, oxygenation saturation in percent calculated as the mean of left and right optode measurements, respectively. Data of four patients—all of whom were from the open TAAA repair group—were of limited use for postoperative analysis, as acquisition could not be continued beyond 5 hours (all acquired data up to this point was equally included in the analyses). One of these patients needed to be manually resuscitated intraoperatively, after compromise of the right coronary artery during heart luxation due to a distinct pectus excavatum. In this patient, both optodes measuring thoracic and one optode measuring the lumbar CN oxygenation dislocated, and thoracic CN oxygenation saturation (ThS) was not available throughout the procedure. Mean calculations at the start of distal perfusion include measurements of the 12 patients where distal perfusion was performed (see Table 1). Statistical analysis of NIRS measurements and blood pressure for patients undergoing TEVAR was performed and reported on separately. As NIRS for CN monitoring has only recently been adopted into clinical practice for TAAA repair at our institution and is still in preliminary testing, measurements were only analyzed retrospectively, without decisive influence on intra- or postoperative management. Demographic data and procedural details of all patients and subgroups are listed in Table 1.

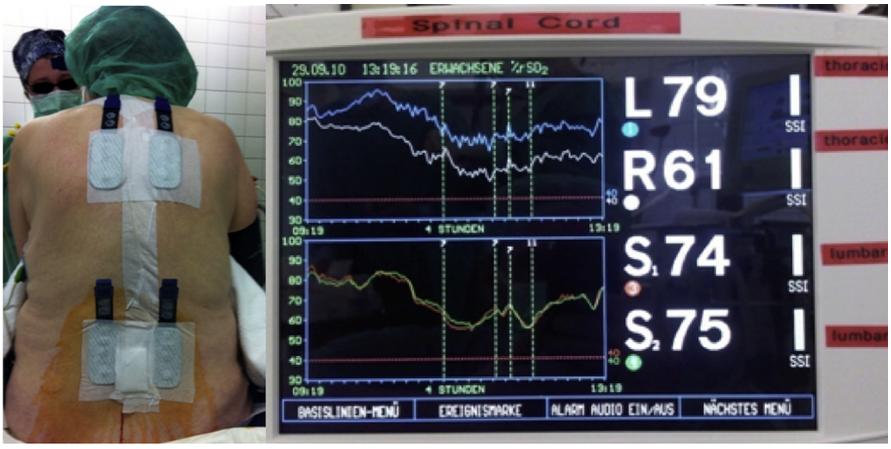

Figure 1. Positioning of the thoracic and lumbar near-infrared spectroscopy (NIRS) optodes (left); real-time NIRS monitor (right).