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CASO CLÍNICO

The Importance of Near-Infrared Spectroscopy for Monitoring Spinal Cord Ischemic Insult During Thoracic Endovascular Aortic Repair

Importância do Espectroscopia Próximo do Infravermelho na Monitorização da Isquemia da Medula Espinal Durante a Reparação Endovascular da Aorta Torácica

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Afiliação
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Palavras-chave
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ABSTRACT

Endovascular aortic procedures are becoming increasingly common, replacing open surgical repair in the majority of patients with thoracoabominal aortic aneurysms. In these procedures, spinal cord perfusion is vulnerable. A high risk patient for spinal ischaemia was presented for a branched 22 cm long thoracic endovascular aortic repair (TEVAR) elective procedure. We used a monitoring approach with a subarachnoid catheter, according to our institutional protocol for TEVAR procedures, complemented with the use of near-infrared spectroscopy (NIRS). Continuous non-invasive surveillance of peri-spinal oxygen supply-demand balance during the procedure (NIRS), together with mean arterial pressure and cerebrospinal fluid pressure trends, was of uttermost importance to help us distinguish the pathophysiology mechanism behind the ischemic insult and act accordingly. NIRS has the potential to satisfy all the criteria for ideal spinal cord monitoring, such as noninvasive, continuous and real-time information about spinal cord perfusion and oxygenation.

RESUMO

Os procedimentos endovasculares estão a tornar-se cada vez mais comuns, substituindo a cirurgia aberta na maioria dos casos de aneurisma aórtico toracoabdominal. Nestes procedimentos a perfusão da medula espinal está vulnerável.

É descrito um caso de um homem com risco para isquemia espinal, proposto para cirurgia eletiva de reparação aórtica torácica endovascular com uma prótese fenestrada de 22 cm. Foi usada uma estratégia de monitorização com recurso a cateter subaracnoideu, de acordo com o protocolo institucional, complementado com a tecnologia de espectroscopia próximo do infravermelho (NIRS). A monitorização não invasiva do balanço entrega-demanda de oxigénio peri-espinal (NIRS), em conjunto com as tendências da pressão arterial média e a pressão do fluido cefalorraquidiano, revelou-se de grande importância na distinção do mecanismo patofisiológico por detrás do insulto isquémico e permitiu atuar em concordância. A tecnologia NIRS constitui uma forma de monitorização da medula espinal próximo do ideal: não invasibilidade, informação contínua e em tempo real acerca da perfusão e oxigenação peri-espinal.

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INTRODUCTION

Endovascular aortic procedures are becoming increasingly common, replacing open surgical repair in the majority of patients with thoracoabominal aortic aneurysms.[1] In these procedures, spinal cord perfusion is vulnerable to hemodynamic variations and the mechanical obstruction of the artery of Adamkiewicz can also contribute to the ischemic insult.

Patient demographic characteristics, comorbidities, anatomic features, and anaesthetic and surgical techniques are known risks factors to spinal cord ischemia (SCI).[2]

In experienced centres despite the use of various strategies to protect spinal cord, the incidence of spinal cord ischemia

ranges from 3.9% to 13.2%.[3] Therefore, close monitoring of the patient during the surgical procedure is mandatory to detect spinal cord ischemia early enough to treat it.

Monitoring spinal cord perfusion and function is in the dependency of the developments made in brain monitoring. Griep *et al* described the "The Collateral Network (CN) Concept " blood supply to the spinal cord is provided by a rich network of intra- and paraspinous arterial collaterals).[4]

Near-infrared spectroscopy (NIRS) is a noninvasive continuous monitoring technique that assesses the oxyhaemoglobin fraction within a focal area of underlying tissue.[5]

There are a few published works reporting its use in spinal cord monitoring. LeMaire *et al*[2] successfully used NIRS in a pig model to detect induced regional SCI and Moerman *et al*[6] used NIRS to detect SCI during a staged hybrid thoracoabdominal aortic aneurysm (TAAA) repair. Nicolaou *et al*[7] have also used NIRS to accurately detect and treat SCI in humans during thoracic endovascular aortic repair (TEVAR). Demir *et al*[8] described two cases of Type B aortic dissection surgery in which spinal regional perfusion monitoring was performed. Etz *et al*[9] evaluated, 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 pilot study, and concluded that Lumbar collateral network oxygenation levels directly respond to compromise of aortic blood circulation. After this, the same workgroup[10] reassert that indirect surveillance of the spinal cord by NIRS seems to be a tempting option with increasing evidence supporting the collateral network concept. To the best of our knowledge, this is the first case to report a differential approach and plan of intervention based on continuous noninvasive surveillance of oxygenation of the spinal cord region during and after a TEVAR.

CASE REPORT

A 77 year-old man with an endoleak type I from a previous EVAR (endovascular aortic repair) and an associated thoracic aneurysm was presented for a branched 22 cm long TEVAR elective procedure. He had a history of three previous general anaesthesia without incidents. His comorbidities included controlled high blood pressure, dyslipidaemia, pulmonary emphysema, chronic renal disease grade II, depression and a previous stroke without present sequelae. He also reported difficulty on climbing a flight of stairs. He had a modified Lee score class III and a modified Frailty Index of 5. Analytically: creatinine 1.21 mg/dL and remaining values within normal ranges; Electrocardiogram: Sinus rhythm, 66bpm, cQRS of 415 ms. Thorax X-ray: emphysematous biotype.

One day before the surgery the anaesthesia team placed a lumbar drain in L4-L5, limiting the depth of catheter insertion to 6 cm in a cephalic direction. The procedure was performed in an angiographic suite outside the OR, with the standards of care indicated in the Statement on Nonoperating Room Anesthetizing Locations. In addition to the American Society of Anesthesiology (ASA) standards we also monitored the haemodynamic status by ProAQT® Pulsioflex, cerebrospinal fluid pressure (CSFP), the spinal cord perfusion pressure (SCPP) (SCPP=MAP-CSFP), the depth of anaesthesia with bilateral BIS® and the regional oxygen saturation (rSO_2) with INVOS®. Regional oxygen saturation was evaluated in four locations in accordance to Broezeman *et al*[3]: 1 - left frontal lobe, 2 - right frontal lobe, 3 - cervical medulla and 4 - low thoracic medulla (Fig. 1).

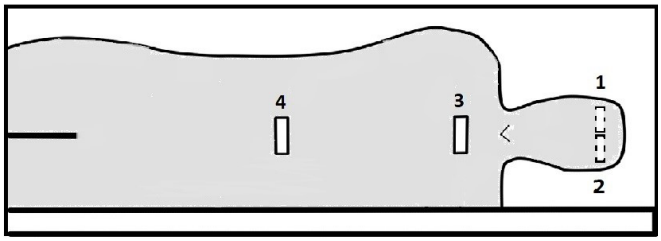

Figure 1. NIRS monitors location: 1 - left frontal lobe, 2 - right frontal lobe, 3 - cervical medulla and 4 - low thoracic medulla

Anaesthesia induction was performed with remifentanil, propofol and rocuronium with minimal hemodynamic repercussions (Fig. 2, point A).

Airway was secured with an endotracheal tube and anaesthesia was then maintained using a target controlled infusion of remifentanil (Minto's model[11]) and propofol (Schnider model[12]). The procedure started (Fig. 2, point B) by surgical exploration of the right femoral artery and left axillary artery allowing accurate endograft placement by angiography and branch cannulation. It was a two-piece endograft. The first piece was placed in the proximal thoracic aorta and the second, thoraco-abdominal, consisted of a four-branch endograft, with branches to the celiac trunk, superior mesenteric artery and both renal arteries.

During deployment and ballooning of the thoracic prosthesis an immediate increase in MAP was verified (Fig. 2, point C). The same haemodynamic response was observed during the deployment of the visceral prosthesis (Fig. 2, point D). The deployment of the visceral prosthesis occludes most of the dorsal arteries below T9, which could explain the systemic hypertension observed during this mechanical phenomena.

The time period between points C and D of Fig. 2 corresponds to the time between the deployment of the two segments of the prosthesis. During this period, a decrease in MAP values and a weak response to vasopressors (phenylephrine) was observed. A significant increase in the CSFP (from 14 to 22 mmHg) was verified and the calculated SCPP was very low (26 mmHg). With respect to rSO_2 monitors, a major decline in the thoracic rSO_2 values (27.4% of the baseline value) was verified. Considering the decline in the thoracic rSO_2 values

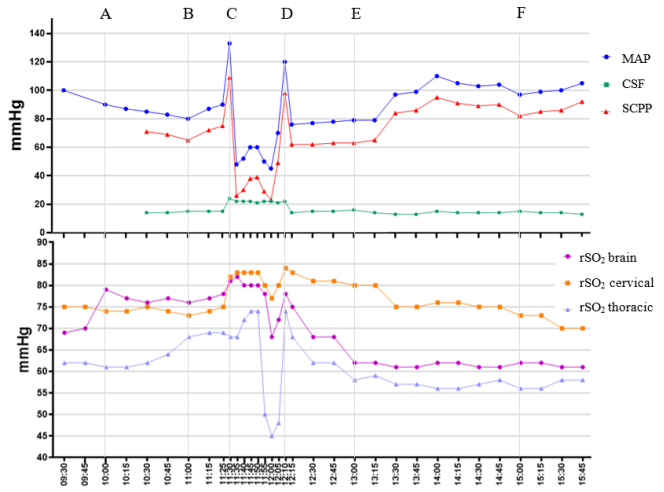

Figure 2. Hemodynamic tendencies, CSFP, calculated SCPP, cerebral and medullar oxygenation during the procedure. A- anaesthesia induction; B- procedure beginning; C- deployment 1st prosthesis; D- deployment 2nd prosthesis; E- CSF drainage; F- anaesthesia emergence

and the increase in the CSFP, 5 mL of CSF was drained (Fig. 2, point E) to improve spinal cord perfusion pressure, according with institutional protocol. After the drainage of CSF, a stabilization of the thoracic rSO_2 values to 10% of the baseline values was observed.

At the end of the procedure, the patient awoke without neurologic deficits. He was immediate transported to the intermediate care unit where he stayed monitored with NIRS during 24 hours, without any events to report. He developed an uncomplicated hospital-acquired pneumonia and eight days after surgery he had hospital discharge. Fig. 3 depicts CT 3D reconstruction of the thoraco-abdominal Aorta with the stents *in situ*.

Figure 3. Postoperative CT-angiography. 3D-Volume rendering, with visceral vessels well-perfused

DISCUSSION

This case illustrates the importance of elaborating a neuroprotective plan to prevent spinal cord ischemia in high risk patients and high risk procedures.[13] In this case, the previous EVAR, the prosthesis length (> 20 cm), the exclusion of T8 to L2 region of the distal thoracic aorta, the advanced age, the renal compromised function and the increased number of comorbidities contributed to a high risk of spinal cord ischemia.

We selected a noninvasive perfusion monitor, NIRS, mainly used to access brain perfusion but already described to be used in the context of spinal cord ischemia.[3,6,7] This monitoring allowed for a better understanding of the pathophysiology of intraoperative TEVAR spinal cord ischemia and an early identification of a possible spinal cord ischemia. In this case, there were two mechanisms contributing to spinal ischemia. On one hand there was systemic hypotension. Takeda et al, demonstrated that endovascular prostheses increases vascular stiffness and induces LV hypertrophy and LA enlargement that is associated with deterioration of diastolic wall strain and deterioration of diastolic function.[14] In this case, the patient had little cardiac reserve (ProAQT® Pulsioflex monitor showed an initial cardiac index of 2.1), and so, it was probably not able to compensate immediately for the increased resistance caused by the new prosthesis, resulting in transitory hypotension that was unresponsive to vasopressors. This systemic hypotension was not enough to interfere significantly with the peri-spinal oxygen supply-demand balance. Cerebral and cervical rSO_2 decreased only 1.4% of the baseline, possibly due to autoregulatory control. This added rSO_2 information was important because it avoided unnecessary invasive measures to maintain the perfusion pressure.

On the other hand, mechanical obstruction of the spinal arteries due to prosthesis deployment added an insult to the spinal cord. The consequences of these two mechanisms can be seen in the decline of the thoracic rSO_2 (27.4% of the baseline). These two insults decontrolled the thoracic spinal cord vascular autoregulation with consequent risk of ischemia. At this time invasive measures had to be made to maintain the spinal cord perfusion.

It is generally accepted that, in the presence of SCI detected clinically or by evoked potentials, MAP should be raised from 75–85 mmHg to 90–100 mmHg. Out of the symptomatic context, the recommended values are more variable and the trend is to maintain MAP 90 mmHg during the intervention to achieve both SCI prophylaxis and neuroprotection.15 Other intraoperative objectives include: cardiac index >2.0 L/min, oximetry 96% and haemoglobin level > 10–12 mg/dL.15 We addressed all these and added one more trend: the spinal cord NIRS compared to the baseline (above -20% of the baseline). This cut-off is extrapolated from the brain

NIRS data, since there is a parallel between cerebral vascular dynamics and spinal vasculature and that brain and spinal cord autoregulation curves are virtually identical within a range of 60-150 mmHg.

In light of this information we drained a small amount of CSF to stabilize the NIRS values. Targets of CSF drainage mentioned in literature vary from maintaining a spinal pressure inferior to 8 mmHg up to 12 mmHg.[15] Some authors suggest to start drainage only if symptoms develop, and a third option is to use evoked potentials for intraoperative neurologic monitoring as a way to adjust the magnitude of the CSF drainage according to eventual alterations in the recordings.[15] Our patient had a starting SCP of 14 mmHg and was asymptomatic, presumably because of a previous abdominal prosthesis and a consequently preadaptation and revascularization.[4]

The completion of deployment together with CSF drainage were associated with NIRS increase to targeted values, thus confining our interventions.

Continuous non-invasive surveillance of peri-spinal oxygen supply-demand balance during the procedure, together with MAP and CSFP trends, was of uttermost importance to help us distinguish the pathophysiology mechanism behind the ischemic insult and act accordingly. NIRS advantages over MEPs monitoring comprise of taking up less surgical space, allowing continuous signal capture and immobility, important practical aspects for this particular procedure. Also does not variates with peripheral ischemia that is common in these patients with chronic vascular disease. Besides that, the MEPs is a painful technique so it cannot be used easily during the pre and postoperative periods. The most important disadvantage of MEPs technique is that they provide delayed data after the occurrence of neural injury. However, additional studies are necessary to correlate NIRS findings with MEPs and SSEPs findings as well as spinal cord oxygenation.

CONCLUSION

NIRS has the potential to satisfy all the criteria for ideal spinal cord monitoring and to provide continuous, real-time information about spinal cord perfusion and oxygenation. Furthermore, continuous non-invasive surveillance of oxygenation of the spinal cord region during the procedure was of uttermost importance to help us distinguishing the pathophysiology mechanism behind the ischemic insult and act accordingly. Spinal cord perfusion is considerable less monitored than brain perfusion, therefore validating the use of NIRS for spinal cord is essential.

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