and detects spinal cord ischemia. However, the internal thoracic arteries (when still present) likely provide too much collateral flow to make high thoracic NIRS routinely useful. The application of mid-thoracic to lumbar NIRS for central nervous system monitoring during thoracoabdominal aortic aneurysm repair is an anatomically and now physiologically supported adjunct in the ever-evolving quest to eliminate spinal cord ischemia. Clinical comparisons with motor-evoked and somatosensory-evoked potentials are warranted.

See Article page e3.

Commentary: Noninvasive monitoring and spinal cord injury: The path from benchtop to bedside

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Despite advances in our understanding of pathophysiology and improvement in surgical techniques, spinal cord injury (SCI) remains the most devastating complication after extensive aortic repair involving the descending aorta. Rates of SCI have remained variable, between 2.9% and 16%, and without significant overall improvement in recent years.¹ The pathophysiology of SCI is related primarily to interruption of blood flow to the spinal cord in the absence of sufficient collateral network (CN) flow.

Although the optimal approach to spinal cord protection is debated, the core principles are minimizing ischemic and reperfusion injury coupled with advanced monitoring techniques.² The use of near-infrared spectroscopy (NIRS) to measure blood oxygen saturation in the paraspinal muscles (theoretically an indirect indication of spinal cord oxygenation) is a promising noninvasive adjunct. This

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CENTRAL MESSAGE

Several techniques are on the horizon for improving spinal outcomes in aortic repair; however, monitoring collateral networks through near-infrared spectroscopy is one of the most promising options.

References

1. Hawkins RB, Mehaffey JH, Narahari AK, Jain A, Ghanta RK, Kron IL, et al. Improved outcomes and value in staged hybrid extent II thoracoabdominal aortic aneurysm repair. *J Vasc Surg.* 2017;66:1357-63.
2. Coselli JS, Green SY, Price MD, Zhang QZ, Preventza O, de la Cruz KI, et al. Spinal cord deficit after 1114 extent II open thoracoabdominal aortic aneurysm repairs. *J Thorac Cardiovasc Surg.* 2020;159:1-13.
3. von Aspern K, Haunschild J, Khachatryan Z, Simoniuk U, Ossmann S, Borger MA, et al. Mapping the collateral network: optimal near-infrared spectroscopy optode placement. *J Thorac Cardiovasc Surg.* 2022;164:e3-15.
4. Etz CD, Kari FA, Mueller CS, Silovitz D, Brenner RM, Lin HM, et al. The collateral network concept: a reassessment of the anatomy of spinal cord perfusion. *J Thorac Cardiovasc Surg.* 2011;141:1020-8.

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technology has been widely studied and applied in a variety of clinical settings, albeit with limited conclusive data, including monitoring plastic surgery flap perfusion, cerebral saturation monitoring in cardiovascular cases, and lower limb perfusion with extracorporeal membrane oxygenation (ECMO).³ The first reports of NIRS monitoring in human aortic repair were published in 2011; however, to date, no published experiments have examined the utility of NIRS monitoring of the entire paraspinal CN.⁴

In this edition of the *Journal*, von Aspern and colleagues present their findings of full paraspinal CN monitoring in a large animal model.⁵ By testing periods of aortic clamping in 10 juvenile pigs, the authors validated their method by

showing that NIRS tracings were highly correlated with perfusion measurements obtained from microsphere absorption. Significant positive correlations were found between progression of both the perfusion and NIRS curves from mid-thoracic (T7-T9) to the lower lumbar (L3-L5) levels ($R = 0.5-0.7$; $P < .001$).

The authors should be commended for their ongoing work in studying this technology; however, the limitations of their study must be considered. First, separate retrospective data were used to approximate NIRS values for the high thoracic levels. This may have contributed to the lack of correlation seen in this region and will require further study. Validation will need to be performed on human subjects, given the anatomic differences between healthy juvenile pigs and adult humans with atherosclerotic or vascular disease.

As we consider the translational implications of this study, several questions linger. Is an indirect measure of the perfusion accurate and applicable in our complex patient population? What threshold of change with NIRS will guide clinical management alterations? Will NIRS prevent poor outcomes in reversible cases, or only indicate that the outcome has occurred? Despite these unanswered questions, this study provides important insight into the potential applications of this technology.

Improvements in our understanding of inflammatory mechanisms, metabolic tolerance, and future pharmacologic options may greatly reduce SCI in aortic surgery; however, the maintenance of adequate CN perfusion remains paramount.² The authors have presented an exciting potential addition to the field of real-time spinal monitoring. Once verified in human subjects, their optode placement may lay the groundwork for how we clinically monitor patients at risk for SCI in the future. We congratulate the authors and anticipate further studies taking these methods from the benchtop to the bedside.

References

1. Rocha RV, Lindsay TF, Friedrich JO, Shan S, Sinha S, Yanagawa B, et al. Systematic review of contemporary outcomes of endovascular and open thoracoabdominal aortic aneurysm repair. *J Vasc Surg*. 2020;71:1396-412.e12.
2. Ghincea CV, Ikeno Y, Aftab M, Reece TB. Spinal cord protection for thoracic aortic surgery: bench to bedside. *Semin Thorac Cardiovasc Surg*. 2019;31:713-20.
3. Chan MJ, Chung T, Glassford NJ, Bellomo R. Near-infrared spectroscopy in adult cardiac surgery patients: a systematic review and meta-analysis. *J Cardiothorac Vasc Anesth*. 2017;31:1155-65.
4. Badner NH, Nicolaou G, Clarke CFM, Forbes TL. Use of spinal near-infrared spectroscopy for monitoring spinal cord perfusion during endovascular thoracic aortic repairs. *J Cardiothorac Vasc Anesth*. 2011;25:316-9.
5. von Aspern K, Haunschild J, Khachatryan Z, Simoniuk U, Ossmann S, Borger MA, et al. Mapping the collateral network: optimal near-infrared spectroscopy optode placement. *J Thorac Cardiovasc Surg*. 2022;164:e3-15.