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Technical Note

# Intraoperative monitoring for spinal radiculomedullary artery aneurysm occlusion treatment: What, when, and how long?

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## Abstract

**Background:** Spinal radiculomedullary artery aneurysms are extremely rare. Treatment should be tailored to clinical presentation, distal aneurysm flow, and lesion anatomical features. When a surgical occlusion is planned, it is necessary to evaluate whether intraoperative monitoring (IOM) should be considered as an indispensable tool to prevent potential spinal cord ischemia.

**Methods:** We present a patient with symptoms and signs of spinal subarachnoid hemorrhage resulting from the rupture of a T4 anterior radiculomedullary aneurysm who underwent open surgical treatment under motor evoked potential (MEP) monitoring.

**Results:** Due to the aneurysmal fusiform shape and preserved distal flow, the afferent left anterior radiculomedullary artery was temporarily clipped; 2 minutes after the clamping, the threshold stimulation level rose higher than 100 V, and at minute 3, MEPs amplitude became attenuated over 50%. This was considered as a warning criteria to leave the vessel occlusion. The radiculomedullary aneurysm walls were reinforced and wrapped with muscle and fibrin glue to prevent re-bleeding. The patient awoke from general anesthesia without focal neurologic deficit and made an uneventful recovery with complete resolution of her symptoms and signs.

**Conclusion:** This paper attempts to build awareness of the possibility to cause or worsen a neurological deficit if a radiculomedullary aneurysm with preserved distal flow is clipped or embolized without an optimal IOM control. We report in detail MEP monitoring during the occlusion of a unilateral T4 segmental artery that supplies an anterior radiculomedullary artery aneurysm.

**Key Words:** Spinal aneurysm, spinal cord ischemia, spinal subarachnoid hemorrhage, transcranial motor evoked potentials

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## BACKGROUND

Spinal radiculomedullary artery aneurysms are extremely rare. Djindjian *et al*.[8] reviewed more than 3000 selective spinal angiographies and found only one aneurysm. These infrequent lesions are associated with spinal cord arteriovenous malformation, arteriovenous fistula, aortic coarctation, aortic arch interruption, bilateral vertebral artery occlusion,[17] polyarteritis nodosa, syphilis, and Klippel–Trenaunay–Weber syndrome,[12,16] although up to 40% of them are idiopathic.[21] Treatment should be tailored to clinical presentation, distal aneurysm flow, and lesion anatomical features.

When a surgical occlusion is planned, we need to evaluate whether intraoperative monitoring (IOM) should be considered as an indispensable tool to prevent potential spinal cord ischemia. Several IOM techniques have been suggested to detect early spinal cord ischemia, such as somatosensory-evoked potentials (SSEP), transcranial motor evoked potentials (TcMEP), or epidural potentials (eMEP), a modification of TcMEP.[9,11,23,24] We present a patient with symptoms and signs of subarachnoid hemorrhage resulting from rupture of a T4 anterior radiculomedullary aneurysm who underwent an open surgical treatment under MEP monitoring.

## MATERIALS AND METHODS

### Case description

A 53-year-old previously healthy female was admitted with a 10-day history of acute thoracolumbar back pain with subsequent development of intense headache, nuchalgia, and mild meningeal irritation symptoms. She had a normal physical examination; Kerning, Brudzinski, and Lhermitte maneuvers were negative. Cranial computed tomography (CT) showed a subarachnoid hemorrhage on the right parietal convexity and a right frontal lesion compatible with a cavernoma [Figure 1]. Selective spinal angiography and angioCT of the left T4 segmental artery demonstrated a fusiform anterior radiculomedullary artery aneurysm measuring 3 mm in diameter and 10 mm along the vessel, with preserved distal flow to the anterior spinal artery [Figure 2]. The lesion was located in the left anterolateral aspect of the spinal cord on the T3 spine level. The Adamkiewicz artery arose from the T8 left segmental artery. Magnetic resonance imaging (MRI) showed a small nodular formation slightly hyperintense on T1-weighted imaging (WI) and hypointense on T2WI at the same spinal level, and a subacute subarachnoid blood clot in the thecal sac. Endovascular embolization was not considered as it was thought to probably cause unintentional distal embolization and ischemia of the spinal cord, or an extremely proximal occlusion without sufficient exclusion of the aneurysm. The patient gave consent for the procedure and underwent an open surgical treatment by MB and CY under intraoperative monitoring with TcMEP.

**Transcranial motor evoked potentials monitoring (threshold-level method)**

The anesthetic protocol used for IOM monitoring always includes total intravenous anesthesia (TIVA) with Remifentanyl and Propofol and the use of muscular relaxants for intubation.

Corckscrew electrodes were placed just anterior to C3 and C4 (as defined by the international 10–20 system), stimulating the precentral gyrus. The stimulus consisted of a 4-pulse train with a 2 ms interpulse interval. Initial stimulus intensity was set at 100 V and increased at fixed increments of 50 V, limiting the maximum voltage

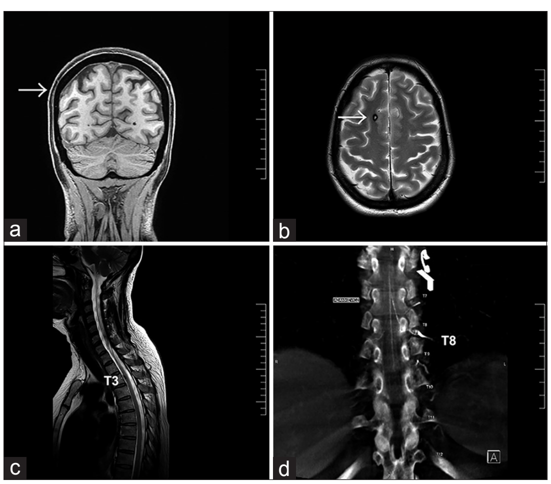


**Figure 1: (a) Coronal MRI view shows subarachnoid hemorrhage on the right parietal convexity (white arrow) (b) Axial MRI view demonstrates a right frontal lesion compatible with a Cavernoma (white arrow). (c) Sagittal MRI shows a small nodular formation at T3 spinal level. (d) Angio-tomography demonstrates Adamkiewicz artery arising from the T8 left segmental artery**

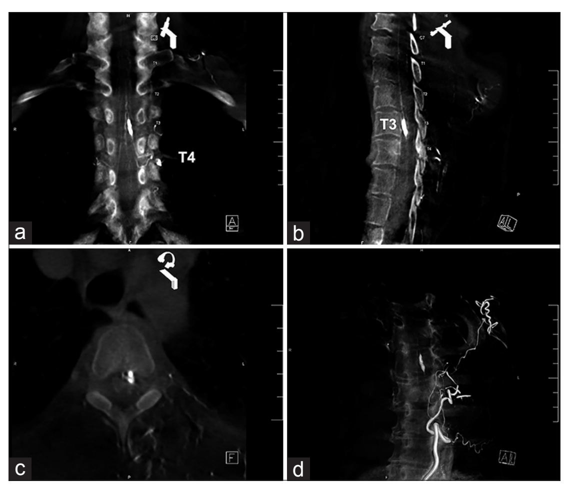


**Figure 2: Angio-tomography 3D reconstruction. (a) Coronal view shows left T4 radiculomedullary aneurysm. (b) Antero-medullary location of the aneurysm al T3 spinal level. (c) Axial view shows left anterolateral location of the lesion. (d) Angio-CT 3D reconstruction of the fusiform anterior radiculomedullary artery aneurysm**

to 500 V and reversing the electrode polarity between stimuli. Myogenic responses were recorded bilaterally with needle electrodes placed in the abductor digiti primi, tibialis anterior, and abductor hallucis muscles. A significant change in MEP threshold after clamping the segmental arteries was defined as a threshold increase of 100 V or more. The threshold method is more sensitive to corticospinal deterioration than the "all or none" method: it assumes that, under unchanged stimulation and anesthesia conditions, the stimulus voltage needed to elicit a minimal compound muscle action potential from a given target muscle will remain relatively constant. Deterioration in central motor conduction and/or lower motor neuron function will be reflected by a need for stronger stimulation intensity, recruiting a large population of upper motor neurons. Hence, if a larger stimulus is needed during segmental cross-clamping, it may reflect critical ischemia of the motor pathways.[5-7]

## RESULTS

Surgical treatment (See video at http://surgicalneurologyinternational.com/video/sni_385_16_vid1.mp4)

A bilateral laminectomy was performed at T3 and T4 levels. The dura was opened under microscope magnification and retracted to improve the surgical field. The anterior radiculomedullary left branch of the T4 segmental artery, the left nerve root, and the denticulate ligament were identified. The dental ligament was sectioned to improve lesion exposure. The spinal cord was gently retracted to the right. A fusiform aneurysm with strong adhesions to the anterolateral surface of the spinal cord and anterior dura was identified. The aneurysm was gently dissected from the yellowish anterior thickened dura. Afferent and distal arteries were identified with evidence of blood flow in the efferent vessel. Due to the aneurysmal fusiform shape and the preserved distal flow, the afferent left anterior radiculomedullary artery was temporary clipped; 2 minutes after the clamping, the threshold stimulation level raised over 100 V, at minute 3, MEPs amplitude became attenuated over 50%. Based on the rapid changes in the MEP, attempts to clip the aneurysm were abandoned. Temporary vessel occlusion was re-opened and MEP threshold and amplitude gradually returned to pre-clamping measures. The radiculomedullary aneurysm walls were reinforced and wrapped with muscle and fibrin glue to prevent re-bleeding. The patient awoke from general anesthesia without focal neurologic deficit and made an uneventful recovery with complete resolution of her symptoms and signs.

## DISCUSSION

The goal of intraoperative electrophysiological monitoring (IOM) is to identify spinal cord ischemia that occurs during the procedure and to guide the intraoperative management to reduce the risks of neurological damage. The choice of the appropriate IOM technique requires understanding of spinal cord blood flow and of the spinal cord physiology, surgical technique, and their interaction.

Arterial supply to the spinal cord derives from the anterior spinal artery (ASA), posterior spinal artery (PSA), and segmental arteries. Perimedullary anastomoses between these arteries are numerous. In the thoracic spine, the segmental arteries originate from the aorta, and after coursing the lateral surface of the vertebral body, they divide on each side into three major branches: ventral (posterior intercostal), dorsal (muscular and cutaneous branches), and medial or spinal.[22] The spinal branch traverses the intervertebral foramen and divides into anterior and posterior spinal canal arteries, and a radicular artery that supplies the dura and nerve root. Only at some levels, the radicular artery originates from distal branches, radiculomedullary arteries, which follow the anterior and/or posterior nerve roots to irrigate the spinal cord; the ASA and PSAs in their course require this additional blood supply through the anterior and posterior radiculomedullary arteries to maintain adequate blood flow to the spinal cord.[13] According to Hong *et al*.,[15] the ASA is a consecutive series of anastomotic vascular loops rather than a single straight artery.

The ligation of the segmental vessels is routinely performed during anterior spine instrumentation, although large series and reviews support the safety of this surgical maneuver,[3,26,28] many reports describe the onset of new neurological deficit as a result of unilateral segmental artery ligation.[1-10,18,20]

We have to consider three principal anatomical features: (1) only a few segmental arteries supply the spinal cord, (2) the anterior radiculomedullary arteries are 6 (range 2–14), whereas the posterior ones range from 11 to 16,[13] and (3) the spinal cord blood supply from T4 to T8 is less profuse. Under these circumstances, the occlusion of a mid-thoracic anterior radiculomedullary artery is more likely to cause cord ischemia.

Several authors have described different IOM methods to measure the potential risk of spinal ischemia by occluding the unilateral thoracic segmental artery: SSEP, TcMEP, or eMEP. However, the time limit to consider the sacrifice of a segmental artery safe in the absence of IOM alteration is poorly reported in the literature. Wu *et al*.[29] measured the potential risk of spine ischemia in a series of 31 patients with thoracic scoliosis by occluding unilateral thoracic segmental arteries under SSEP monitoring 5 min before occlusion and 2, 7, 12, and 17 min after blood flow interruption. They found that the SSEPs changed significantly within 7 min after occlusion, especially

2 min after vessel clamping (potential latency increased an average of 3.39% and amplitude decreased 26%) compared to pre-occlusion levels, but began to restore at 12 min after clamping and completely returned to the preoperative values at 17 min. They suggested that spinal cord ischemia could follow a dynamic course and that the occlusion of segmental arteries may be safe under SSEP monitoring. Usually when SSEP amplitude values drop more than 50% and latency increases over 10%, it is considered an evident risk of spinal cord ischemia,[1,9,13,29] but SSEPs only reflect conduction of sensory information in the posterior column, which has a different blood supply from that supplying the motor system located in the anterolateral part of the spinal cord. Since this neurological pathway is thought to be the last to become ischemic, in our understanding, this method has limited clinical use.

Epidural MEPs are derived from TcMEPs and require the placement of a special epidural stimulator. TcMEPs are the most suitable technique to detect early spinal ischemia given that they measure corticospinal tract and lower motor neurons, supplied by the anterior spinal artery. The threshold-level described by Calancie *et al*. proved to be more sensitive to early corticospinal tract deterioration than the “all or none” method. Usually, when MEP threshold increases more than 100 V (or MEP amplitude decreases more than 30%) it is considered a warning sign of spinal cord ischemia.[5-7] The clue in IOM is that changes must be quickly noticed so that the surgeon can reverse the maneuver. In our case, the MEPs findings after 3 min of the temporary radiculomedullary artery occlusion, led us to remove the vessel clamping and modified our surgical strategy to preserve the spinal cord blood supply. Given that this one is a case report, no firm recommendation can be drawn from our observation. Further reports of similar cases may add new information to this subject.

IOM can be associated to endovascular network techniques such as indocyaine green fluorescent dye (ICG) videoangiography before and after clipping. This intraoperative angiography integrated to a surgical microscope allows the surgeon to evaluate real-time images of arterial, capillary, and venous flow; thus, to recognize spinal cord ischemia even before IOM. However, this technology is not available worldwide, it is time consuming, expensive, requires additional experienced staff, and bears a complication rate of 0.4–2.6%.[2]

The use of epidural or intradural electrodes to measure D-wave is very useful to improve the accuracy of IOM during surgery in and around the spinal cord, but unfortunately it was not easily available in our country by the time this procedure was performed.

Surgical treatment should be considered only if connective tissue disorders, inflammatory and noninflammatory vasculopathies are excluded as the underlying etiology, mainly because under these circumstances aneurysms may thrombose or spontaneously regress with the primary pathology control.[4,27]

In cases of aneurysm rupture, prompt occlusion should be considered to remove the associated blood clot or to prevent a possible devastating re-bleeding. If there is no evidence of distal flow, the aneurysms can be obliterated with occlusion of the parent vessel.[12] If the distal flow is preserved, endovascular or open surgical treatment could be performed under IOM. If potential monitoring tolerance to temporary occlusion reveals no neurological deficit, obliteration can be intended as the definitive treatment measure. If MEP warns of potential risk of spinal cord ischemia, flow preserving techniques, such as endovascular treatment, wrapping or direct microvascular reconstruction can be attempted.[12,14,19,25,27]

We describe a clear warning of possible spinal cord ischemia, within 2 minutes of temporary occlusion of the radicular artery, the threshold for MEP increased more than 100 V, and at minute 3, MEP responses vanished despite increasing the stimulus voltage.

## CONCLUSIONS

This paper, attempts to build awareness of the possibility to cause or worsen a neurological deficit if a radiculomedullary aneurysm with preserved distal flow is clipped or embolized without an optimal IOM control. We report in detail the behavior of the MEPs monitoring during the occlusion of a unilateral T4 segmental artery that supplies an anterior radiculomedullary artery aneurysm.

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### Conflicts of interest

There are no conflicts of interest.

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