



The value of intraoperative neurophysiological monitoring during positioning in pediatric scoliosis correction: A case report



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ABSTRACT

Introduction: Prone position during posterior spine surgery can represent a potentially risky procedure for the nervous system. Infrequent injuries due to prone positioning consist of subtle spinal cord infarction or myelopathy that can be promptly detected by intraoperative neurophysiological monitoring (IONM), if applied in this phase of surgery. Here, we report a case that stresses the value of IONM even in detecting spinal positioning-related neurological complications during kyphoscoliosis correction.

Case presentation: A 3-year-old child with a severe thoracic kyphoscoliosis with the angle in the tract T5–T6 underwent an early treatment of scoliosis with growing rods. Before instrumentation or the reduction maneuver, lower limb somatosensory and motor responses disappeared. The patient was repositioned with neck and chest in a more protective position and neuromonitoring signals returned to baseline. The surgery could be completed and the patient had no postoperative neurologic or vascular deficits.

Conclusion: Our findings suggest the importance of extending neuromonitoring in the early phases of anesthesia induction and patient positioning during corrective spinal deformity surgery.

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1. Introduction

The spinal cord damage is one of the most severe complications during thoraco-lumbar spine surgery. The incidence of the risk is difficult to quantify because it depends on the type and duration of surgery, the vertebral level implicated and surgical approach, patient's vascular network and spinal liability. Nevertheless, it can be estimated varying from 0.69 to 1.75% (Coe et al., 2006), but those numbers refer to adolescent idiopathic scoliosis and do not include more severe clinical conditions. Indeed, the rate rises to 22.18% in surgery involving up to three-column spine reconstructions for complex spinal deformity (Kelly et al., 2014).

Neurological consequences of spine surgery can be the direct product of stretching of spinal cord due to surgical maneuvers or indirectly associated with a hypoperfusion during preparation for surgery, intra- or postoperatively (Hemmer, 2018).

Although overlooked, prone positioning during posterior spine surgery is a key step that should be highly considered to avoid post-operative neurological complications, in particular in patients with cervical and craniovertebral junction pathologies (Graham

et al., 2018; Appel et al., 2017; Uribe et al., 2010; Suzuki et al., 2003; Edgcombe et al., 2008). Indeed, compressions and/or tractions of spinal cord and nerve trunks at different level can be directly attributed to prone position (DePasse et al., 2015; Garreau de Loubresse, 2014). The most common neurological lesions are related to ulnar nerve, brachial plexus, and anterior superior iliac region (Uribe et al., 2010; Mirovsky and Neuwirth, 2000; Akagi et al., 1976), but other infrequent positioning-related complications can involve spinal cord ischemia or myelopathy. For instance, some studies have reported cases of bilateral femoral artery ischemia associated with a combination of mechanical and ischemic effects by hypoperfusion secondary to prone positioning (Tseng et al., 2010; Vossler et al., 1976).

In this scenario, intraoperative neurophysiological monitoring (IONM) can be an effective tool to be used for both surveillance and prevention of such overwhelming injuries (Jahangiri et al., 2011).

Multimodal IONM allows to record somatosensory and motor evoked potentials (SSEPs and MEPs, respectively) providing complete information on the status of spinal cord and nerve roots during corrective procedures (Plata Bello et al. 2015; Chung et al., 2009). The main goal of IONM is to identify imminent spinal cord injury at a reversible stage, monitoring with minimal delay in acquisition. This provides a real-time feedback to the surgeon which can permit greater surgical intervention or assurance that

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spinal cord function is being maintained during the course of the operation. IONM also plays an important role in prognosis, when a spinal cord injury happens.

SSEPs assess the dorsal column of the spinal cord and are sensitive to peripheral nerve and plexus compromise due to malpositioning (Kamel et al. 2006; Labrom et al. 2005). A recent study reported that the 93.75% of the upper limbs IONM alerts involving SSEP changes were related to patient positioning (Polly et al., 2016). On the other hands, MEPs provides supplementary safety for emerging motor nerve injury not identified by SSEPs alone (Schwartz et al. 2006).

Here, we describe a case that further emphasizes the value of IONM in detecting spinal positioning-related neurological complications during kyphoscoliosis correction.

2. Case presentation

A three-year-old child with suspicious Shinzel-Giedion syndrome presented with a severe thoracic kyphoscoliosis with the angle in the tract T5-T6 (Fig. 1). Clinical history included dysmorphic facies and psychomotor delay. The patient was able to walk with assistance. The spine CT scan (see Fig. 1) revealed severe angular thoracic kyphosis with the angle in the tract T5-T6 which were slightly reduced in height anteriorly with a tendency to an anterior wedge shape. A schisis of the posterior arch of the atlas and the second cervical vertebra was described. C2 also presents with dens axis apex sloped posteriorly and a dysplastic posterior arch associated to a bifid spinous process.

Forty days before the surgical procedure, the patient underwent a halo-gravity traction applied in the attempt to improve cervical deformity and pulmonary function, and avoid too acute corrections of his rigid curves during surgery. The traction started with a low amount of weight (1.5 kg) and gradually increased to 5 kg over 6 weeks. The halo ring was removed immediately before performing the surgical procedure.

Surgical procedure consisted of a spinal growing rods treatment. It consists of the insertion of pedicle screws or hooks, leaving a non-instrumented intervertebral joint above and below the upper and lower instrumented vertebrae. Then, two growing rods are inserted and assembled to control the deformity preserving spine and thorax growth (Bekmez et al., 2017).

Cardiovascular and anesthesia preoperative assessments were within normal limits.

During surgery, the patient was intubated with a 5.0 endotracheal tube and a central venous catheter (CVC) was inserted. Anesthesia was induced and maintained with intravenous propofol (4.5 ug/ml) and remifentanyl (9.6 ml/h).

Neurophysiological measures consisted of monitoring SSEPs by cork screw electrodes placed over the primary somatosensory cortex at sites C3', C4' and Cz', referred to Fz, according to the 10–20 international system of electrode placement. Stimulation was provided through subdermal needle electrodes placed over the posterior tibial nerve at the medial malleolus and the median nerve at the wrist. The stimulus intensity was set to induce a muscle twitching, at a rate of 4.79 Hz. Recordings were averaged using a bandpass filter of 10 to 500 Hz and automatically stored after 300 stimuli repetitions.

For transcranial electrical MEPs the site of stimulation was reversed, and cathode/anode were identified 1 cm anterior to the C3 or C4 electrode site overlying the motor cortex area. Stimulation consisted of a seven-pulse train with an interstimulus interval of 400 ms set at 250 to 500 V. Compound muscle action potentials were recorded from the bilateral abductor digiti minimi (ADM), rectus abdomini, iliopsoas, rectus femoris, tibialis anterior, and flexor hallucis brevis.

After the anesthetic regimen was established, intraoperative baseline sensory and motor evoked potentials were detected in supine position. MEPs showed good morphology and reproducibility (Fig. 2A). Posterior tibial and median nerves SEPs were also reproducible bilaterally (Figs. 3 and 4A).

After supine recordings, the patient was placed prone on the surgical table, supported by gel rolls placed one across chest just above the level of axilla and one across iliac crest (see Fig. 5A). The neck was in neutral position with the head turned to the same side of CVC, not exceeding the patient normal range of motion and avoiding hyperextension of cervical vertebrae. The elbows were flexed, the hips were completely extended and knees slightly flexed with an anterior foam padding.

Baselines responses remained stable while the patient was placed in the prone position (Figs. 2B, 3 and 4B).

After twenty minutes from the beginning of the procedure, while muscles were stripped off to reveal facet and transverse pro-

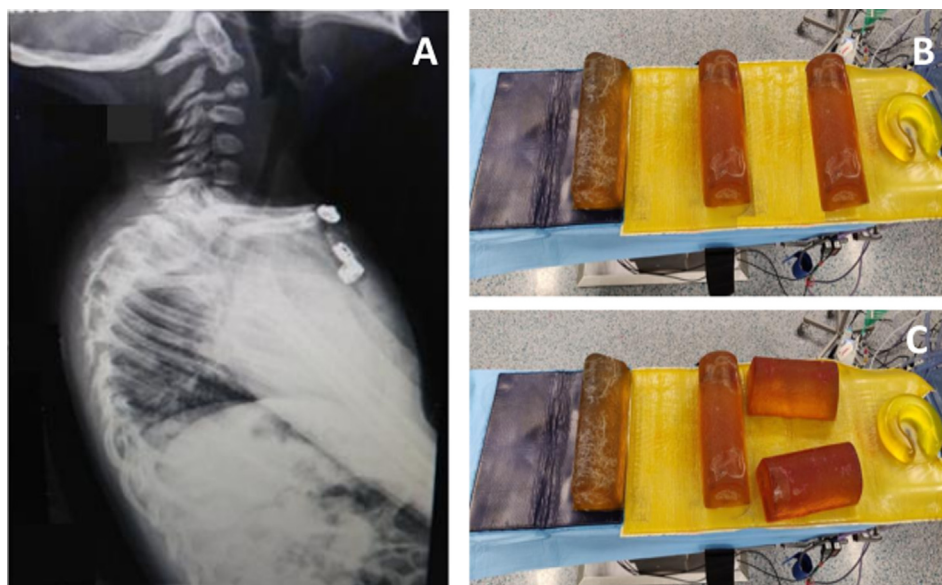


Fig. 1. Preoperative radiographies. Lateral and anteroposterior imaging demonstrating the severe kyphoscoliosis with the angle in the tract T5-T6 and some pre-existing malformations at cervical level.

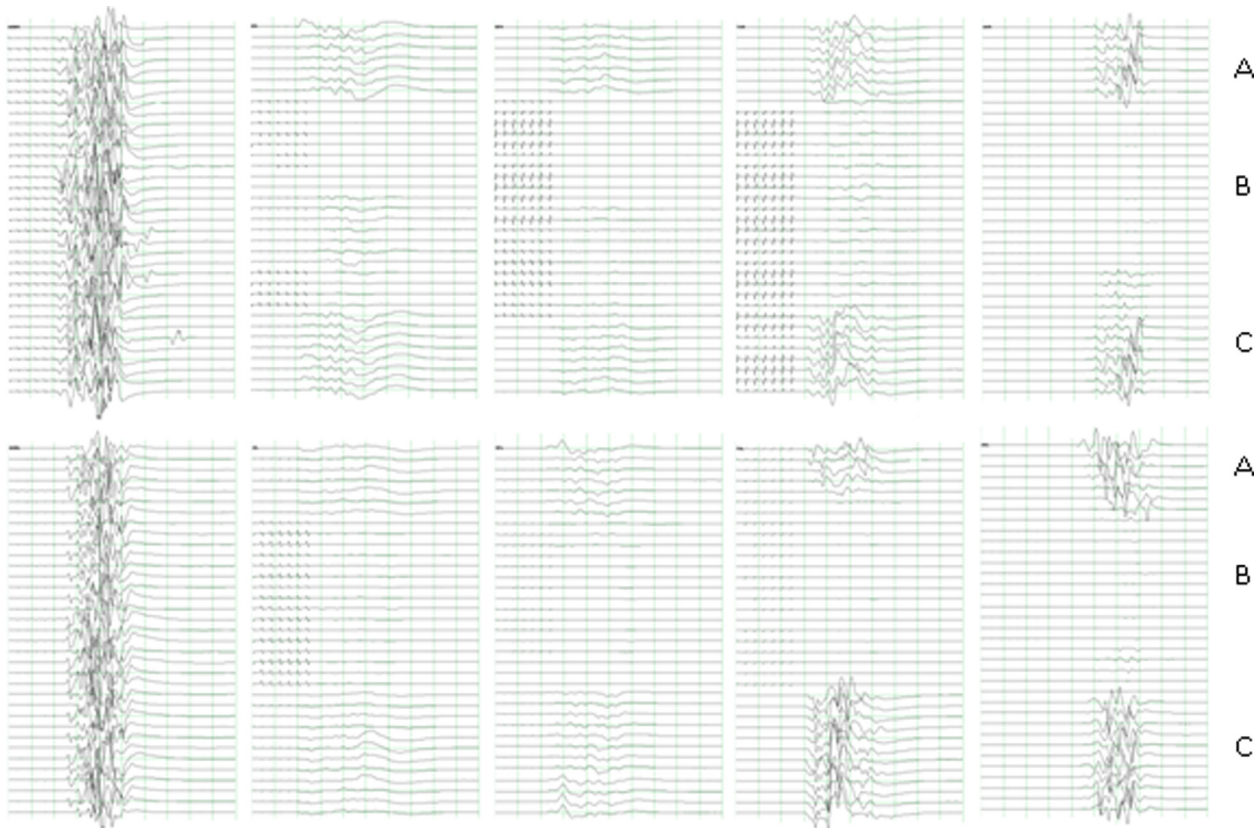


Fig. 2. Motor-evoked potential (MEPs) from the right and left side. MEPs are recorded in prone position at time prior to the alert (A), at alert (B) and after the repositioning of patient (C). At alert, note loss of responses in lower limbs and no changes in upper limbs. After the repositioning of patient, there is a complete recovery of evoked potentials. Muscles illustrated from left to right were: abductor digiti minimi (ADM), iliopsoas (IP), rectus femoris (RF), tibialis anterior (TA) and adductor hallucis (AH). The top is the right side, the bottom, the left side.

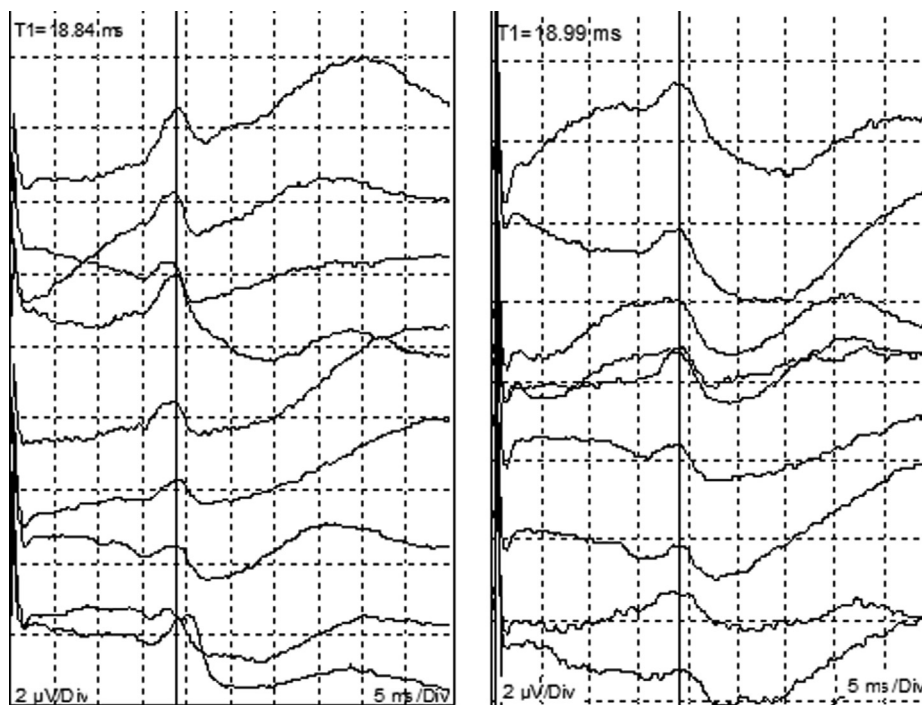


Fig. 3. Upper limb somatosensory evoked potentials obtained by ulnar nerve stimulation at the wrist (ULSSEPs). The potentials did not change at alert and were stable during the course of surgery. Here represented the left and right side, respectively.

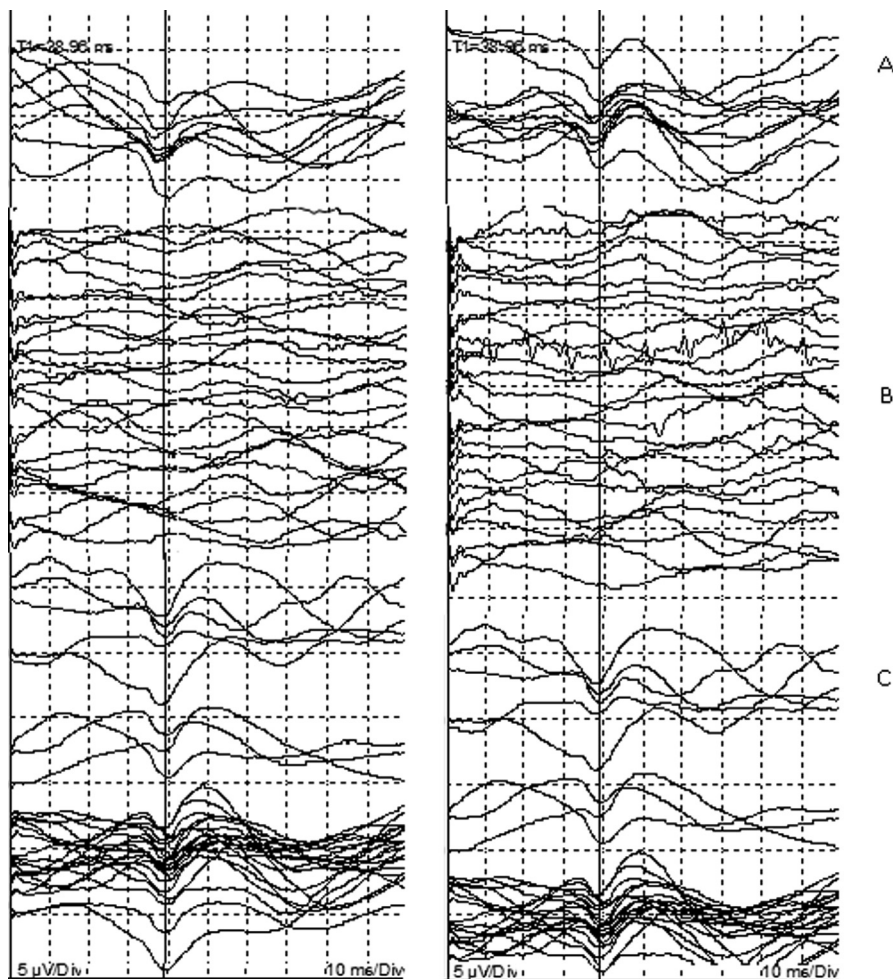


Fig. 4. Lower limb somatosensory evoked potentials obtained by tibial nerve stimulation at the ankle (LLSSEPs). They recorded in prone position (A) 20 min prior to the alert (B), at alert (C) and after the repositioning of patient (D). After the change of position of patient, a normalization of evoked potentials could be seen. Left and right side are represented, respectively.

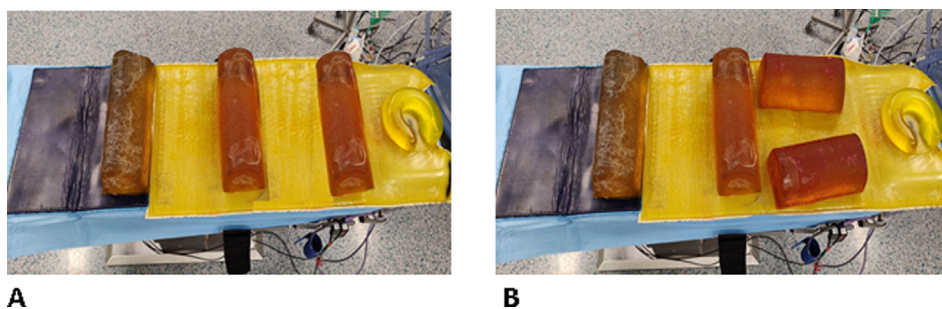


Fig. 5. View of pads with patient in prone position on the surgical table. **A.** Gel rolls are placed one across the chest above the level of axilla and the other one across the iliac crest. **B.** The chest is optimally placed centered over two parallel pads.

cesses, lower limb motor responses disappeared, immediately followed by a significant decrease (under 50% from baseline) of lower limb somatosensory potentials (Figs. 3 and 4C). Only bilateral ADM was preserved (Fig. 2C). The patient continued to show stable hemodynamic parameters.

The surgeons were notified that EPs were no longer present and they decided to lighten anesthesia. During the wake up test, the patient demonstrated progressively spontaneous controlled movements of his trunk and lower extremities.

Once the test was complete and the patient was re-induced, the positioning was carefully checked and some adjustments were made. Chest was placed on parallel rolls and particular attention was paid to the neck placement, in a position with flexion limited to less than 15° from horizontal (Fig. 5B).

After position adjustment, there was gradual recovery of bilateral lower limb potentials that remained stable throughout the instrumentation and fusion giving reassurance that the spinal cord was not compromised. Postoperatively, the child had no neurologic deficits.

3. Discussion

Although rare, iatrogenic spinal cord injury is one of the most serious complications of corrective spinal deformity surgery. In this context, neurophysiological monitoring plays an essential role providing online evaluation and feedback to prevent irreversible neural damage that can occur during, before and after surgery (Pauchard et al., 2014).

Neuromonitoring offers the opportunity for rapid intervention to prevent injury progression and possibly reverse impending neurologic sequelae.

In our study, the patient showed an acute high-thoracic spinal cord suffering during posterior thoraco-lumbar arthrodesis in a clinical picture of pre-existing cervical displacement. This was immediately identified by the use of multimodal IONM.

The origin of the alterations of our neurophysiological signal is multifactorial. Despite the lack of complications directly related to surgical maneuvers, the malpositioning associated with a thin body habitus with underdeveloped musculature, ligamentous laxity, and loss of muscle support due to anesthesia could be the cause of a fall of the evoked potentials. In a picture of general anesthesia which allows increased joint mobility and obliterates any protective reflexes compared with the awake state, hyperextension of the neck during intubation and positioning is critical. Especially in patients with severe cervical deformities and unstable spines, intubation should be done with the support of a fiberscope without hyperextending the neck. After intubation, transfer of the patient in prone position should be performed safely with a careful control of the spine. Prone positioning during posterior spinal surgery is a maneuver that should be prudently performed in order to avoid potentially permanent post-operative complications (Uribe et al., 2010; Welch et al., 2009; Suzuki et al., 2003). For instance, a different placement of rolls lengthwise along the sides of the chest to facilitate ventilation, stabilize neck, and raise the body weight off the abdomen and thorax could be a method to prefer in the surgical environment. To be completely helpful, IONM baselines should be obtained in supine position enabling to monitor the spinal cord throughout the entire stage of positioning.

Associated with the position of patient, stretching of the spinal cord over the kyphotic knuckle (T5-T6) during its exposure would explain the loss of neurophysiological responses above the apex of kyphosis. This may be supported by the initial absence of MEPs followed by the reduction of SSEPs, likely due to a vascular mechanism involving spinal arteries. In fact, the tract T4-T8 is considered to be a potential vascular watershed zone rendering these levels susceptible to transient perfusion abnormalities (Dommissie, 1974). The high metabolic demand of the spinal gray matter makes MEPs sensitive to changes in spinal cord blood flow (Pastorelli et al. 2011). This allows time window for an intervention to avoid ischemic consequences.

Therefore, in thoracic surgery, hypotension should be avoided and the mean arterial blood pressure maintained higher than 80–85 mmHg in cases where the spinal cord is already at risk. However, local factors (e.g. spinal stenosis, distractions, skeletal instability) may contribute to be more vulnerable to regional hypoperfusion even at safe systemic blood pressure. This poses a challenge to further study patients who are at risk of suboptimal perfusion with hypotensive anesthesia. Therefore special attention must be given ensuring adequate spinal cord perfusion in all patients.

After the loss of evoked responses, the wake-up test progressively restored muscle tone and/or regional blood perfusion permitting spontaneous movements and the reappearance of potentials. Patient positioning was reexamined and corrected and

electrophysiological recordings returned to baseline until the end of surgical procedure.

This case emphasizes that IONM can be employed not only to detect intra-operative warnings due to surgical maneuvers, but also as a guide during positioning into positions more favorable to protect nerves and spinal cord from injury (Vauzelle et al., 1973). However, there is still a debate about the alarm criteria (decrease of amplitude, increase of latency, changes in morphology or in stimulus threshold of evoked potentials) and the definition of false positive and true positive.

Some authors consider cases in which a fall in evoked potentials is not followed by postoperative neurological deficit, as false positive, even if correlated with an intraoperative event at risk for spinal cord (Kim et al., 2007). Others sustain that true positive would be any case in which significant loss of potential is reversed by an intervention (Hilibrand et al., 2004). Further investigations are needed to find the cause-effect correlation and increase the validity of meaning of true and false-positive alerts.

Nevertheless, multimodal intraoperative monitoring is considered “standard of care” during pediatric spine surgery, able to predict and prevent new postoperative deficits and its efficacy can improve using protocols tailored on individual patient needs and characteristics.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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