World Journal of Surgery and Surgical Research

Review Article
Published: 05 Dec, 2022

Assessment of Intraoperative Neurophysiological Monitoring Techniques in Intramedullary Spinal Cord Tumor Removal Surgery

Nguyen MA, Ngo AP, Huynh QB and Pham TB*

Department of Neurosurgery, University Medical Center, Ho Chi Minh City, Vietnam

Abstract

Objective: Intraoperative neurophysiological monitoring in intramedullary spinal cord tumor removal surgery helps surgeons detect early warning signs of postoperative nerve damage, in order to reduce or prevent permanent neuron injury. We performed a study to evaluate the value of intraoperative neurophysiological monitoring techniques in intramedullary spinal cord tumor resection surgery.

Methods: We performed a retrospective study of 29 patients undergoing surgery for intramedullary spinal cord tumors and intraoperative neurophysiological monitoring during the period 2017-2021 at the University Medical Center, Ho Chi Minh City. Clinical assessment before and after surgery, intraoperative neurophysiological monitoring in surgery to find out the sensitivity, specificity, positive predictive value, and negative predictive value of intraoperative neurophysiological monitoring techniques.

Results: Of the 29 patients, 4 patients had worse postoperative neurological symptoms 13.8% at 1 day after surgery, then decreased to 10.3% at 1 month after surgery. SSEP (somatosensory evoked potential) has 75% sensitivity, and 72% specificity in detecting postoperative nerve damage, while the sensitivity and specificity of MEP (Motor Evoked Potential) are 100% and 80%, respectively.

Conclusion: Both SSEP and MEP have high sensitivity in detecting postoperative nerve damage, meanwhile, MEP is more sensitive than SSEP. These techniques help predict and possibly prevent timely neurological damage during intramedullary spinal cord resection surgery.

Keywords: Intraoperative neurophysiological monitoring; Somatosensory evoked potential; Motor evoked potential; Intramedullary spinal cord tumor

Introduction

Surgery to remove intramedullary spinal cord tumors is a complex technique, that tends to lead to many neurological injury complications. The rate of neuron damage varies by author, from 10.9% to 34.6% [1,2]. Intraoperative neurophysiological monitoring has been shown to be supportive in spinal cord tumors surgical resection [3]. However, in Vietnam, intraoperative neurophysiological monitoring is still quite new. Ho Chi Minh City University Medical Center is the first medical facility in Vietnam to apply intraoperative neurophysiological monitoring techniques in surgery both cranial and spinal surgery. In which, intraoperative neurophysiological monitoring in intramedullary spinal cord tumor removal surgery is routinely applied. The methods used in combination include SSEP and MEP. SSEP is the average potential of multiple stimuli. It reflects the integrity of the upward sensory pathway. Although it is not sensitive in detecting root damage immediately, it has a high predictive value of postoperative neuron damage if the SSEP changes [4,5]. MEP assesses the integrity of the motor pathway from the motor cortex that conducts pyramidal conduction down the spinal cord and out to the muscle. The sensitivity and specificity of MEP vary by author, in which the sensitivity is quite high [3]. We designed a retrospective study to evaluate the sensitivity, specificity, positive predictive value, and negative predictive value of these techniques in intramedullary spinal cord resection surgery and to evaluate the outcome of surgical resection of intramedullary spinal cord tumors that have intraoperative neurophysiological monitoring, thereby comparing with other studies in the world, creating a premise for the development of these techniques in Vietnam.

OPEN ACCESS

***Correspondence:**
*Anh Phung Ngo, Department of Neurosurgery, University Medical Center, Ho Chi Minh City, Vietnam,
E-mail: phung.na1@umc.edu.vn*

Received Date: *31 Oct 2022*
Accepted Date: *28 Nov 2022*
Published Date: *05 Dec 2022*

Citation:
Nguyen MA, Ngo AP, Huynh QB, Pham TB. Assessment of Intraoperative Neurophysiological Monitoring Techniques in Intramedullary Spinal Cord Tumor Removal Surgery. World J Surg Surgical Res. 2022; 5: 1424.

Materials and Methods

Study design, setting and participants

The patients underwent surgery to remove intramedullary spinal cord tumors at the Neurosurgery Department of the University Medical Center, Ho Chi Minh City, Vietnam, and underwent intraoperative neurophysiological monitoring from January 2017 to December 2021. Demographic characteristics such as age, gender, pre- and post-operative clinical features, and factors related to treatment were collected. Patients with new neurological signs, or more severe neurological symptoms, were defined as positive cases. In surgery has fully monitored techniques including SSEP, and MEP.

Anesthesia

General anesthesia with Fentanyl and Propofol maintained MAC ≤ 0.5. Muscle relaxants use an initial dose to induce anesthesia and intubation, and then do not repeat it. TOF is monitored every 30 min, ensuring over 70% (use muscle relaxants antidote if necessary) to help monitor MEP more accurately. Monitor pulse, blood pressure, SpO2, electrocardiogram, and patient temperature throughout the surgery.

Intraoperative monitoring

Check resistance, make sure electrode resistance value <5 kΩ. SSEP is stimulated in the tibial nerve, the median nerve with an intensity of 20 mA to 60 mA, creating the highest wave intensity, frequency of 5.1 Hz, and wave time of 300 ms. Receive SSEP waves with a period of 100 to 300 depending on the patient. Take SSEP background wave before skin incision, and monitor SSEP continuously. SSEP reduction in intensity >50% or latency time >10% were considered significant changes. Stimulating MEP at C1, and C2, recording response in abductor hallucis and abductor pollicis brevis muscles. The excitation intensity increased gradually from 200 V to 1000 V, recording the strongest wave response.

Statistical analysis

Synthesize the results of intraoperative monitoring and clinical, thereby calculating the sensitivity, specificity, positive predictive value, and negative predictive value of each technique. True positive was defined as the presence of intraoperative positive test and the postoperative clinical worsening neurologic signs. In contrast, the true negative is an intraoperative negative test and the postoperative clinical neurologic outcome is not worse. The false positive is the presence of an intraoperative positive test but the postoperative clinical neurologic outcome is not worse. False negatives mean that there is no intraoperative positive test, but postoperative clinical neurologic signs worsen. Sensitivity is equal to true positive/(true positive + false negative). Specificity is equal to true negative/(true negative + false positive). Positive predictive value is equal to true positive/(true positive + false positive). Negative predictive value is equal to true negative/(true negative + false negative).

Results

Patient characteristics

During the period January 2017 to December 2021, we had surgery to remove intramedullary spinal cord tumors and intraoperative neurophysiological monitoring in 29 patients. The average age is 42.3 ± 14.0, the youngest is 19 years old and the oldest is 68 years old, focusing mainly on the group under 60 years old, accounting for 89.7%.

The gender distribution is not equal between the two sexes, with a male/female ratio of 2.2/1. The most common pathology was ependymoma (44.8%), followed by astrocytoma (31%), and other less common lesions. The most common location was in the cervical region (51.7%), and the thoracic region accounted for a lower proportion (37.9%) (Table 1).

Table 1: Demographic data of patients who underwent intramedullary spinal cord resection surgery with intraoperative neurophysiological monitoring.

Factor	Total n (%) (n=29)
Sex	
Male	20 (69.0)
Female	9 (31.0)
Age (year)	
Mean ± SD	42.3 ± 14.0
<40	12 (41.4)
40-60	14 (48.3)
>60	3 (10.3)
Histopathology	
Astrocytoma	9 (31.0)
Ependymoma	13 (44.8)
Hemangioblastoma	2 (6.9)
Hemangioma	2 (6.9)
Cavernoma	2 (6.9)
Lymphoma	1 (3.5)
Location	
Cervical	15 (51.7)
Cervicothoracic	2 (6.9)
Thoracic	11 (37.9)
Thoracolumbar	1 (3.5)
Worsen outcome	
1 day postoperative	4 (13.8)
1 month postoperative	3 (10.3)

The worse neurological symptoms 1 day after surgery appeared in 4 cases, accounting for 13.8%, then recovered in 1 case, so the rate decreased to 10.3% (Table 1).

Data of intraoperative neurological monitoring

SSEP: Significant changes in SSEP waves occurred in 10 cases, accounting for 34.5%. The change in amplitude decreased by more than 50% seen in all 10 cases. In no case did the changing pattern extend the latency time by more than 10%. SSEP results are as follows: Sensitivity: 75%, specificity: 72%, positive predictive value: 30%, negative predictive value: 94.7% (Table 2).

MEPs: Significant changes in the MEP wave occurred in 9 cases, accounting for 31.0%. The type of change is to reduce the amplitude by more than 80%. MEP results are as follows: Sensitivity: 100%, specificity: 80%, positive predictive value: 44.4%, negative predictive value: 100% (Table 2).

Discussion

Postoperative neurological defect in our study was 13.8% at 1 day after surgery, then there was 1 case of recovery, so the rate was 10.3%. Compared with other authors, our neurological deficit is lower [1,2]. Postoperative sensory deficits are a common consequence of posterior column dissection for intramedullary spinal cord tumor removal

Table 2: Results of the intraoperative neurophysiological monitoring techniques.

Techniques	Worsen outcome (n)	Better outcome (n)	Sens (%)	Spec (%)	PPV (%)	NPV (%)
SSEP	4	25	75	72	30	94.7
Positive	True positive =3	False positive =7				
Negative	False negative =1	True negative =18				
MEP	4	25	100	80	44.4	100
Positive	True positive =4	False positive =5				
Negative	False negative =0	True negative =20				

Sens: Sensitivity; Spec: Specificity; PPV: Positive Predictive Value; NPV: Negative Predictive Value

surgery. The length of the myelotomy was found to correlate with postoperative sensory dysfunction in several studies [6-8]. Tumors that can be removed without causing sensory disturbance are those that have reached the pia mater, pushing the spinal cord to one side. In such cases, resection does not require a myelotomy and the tumor can be accessed directly. This is common in angioblastoma [4], and less in astrocytoma [9].

In our study, ependymoma was the most common (44.8%), followed by astrocytoma (31%). Other types of tumors are less common. This result is similar to the studies of other authors [10]. Ependymomas require more dissection of the inside of the spinal cord; the primary tumor feedstock arteries arise from the anterior spinal artery and require isolation, hemostasis, and resection before the tumor can be removed. This maneuver can lead to injury or excessive strain on the anterior spinal artery. Distinguishing ependymoma tumor tissue from healthy spinal cord tissue is not difficult, so nerve damage is mainly due to vascular damage. On the other hand, astrocytoma's have no such vascular supply but tend to infiltrate normal spinal cord tissue, making it difficult to distinguish between tumor tissue and healthy tissue. The rate of permanent nerve damage following resection of these tumors may indicate that spinal cord tissue was infiltrated during surgery. In any case, maintaining adequate blood pressure during microsurgery cannot be overemphasized [10,11].

The most common location was in the cervical region (51.7%), and the thoracic region accounted for a lower proportion (37.9%). The impact of the location of intramedullary spinal cord tumor on surgical outcome had been underestimated compared with the pathology or resection rate. But some authors addressed this issue, and reported that thoracic lesion is associated with poorer functional outcome. They compared neurophysiologically data and neurological outcomes between cervical and thoracic lesions precisely, and found the significant impact that the affected spinal level has on the neurophysiological and neurological outcome even when pathologies and procedures not different [9,12].

In our study, the SSEP has a high sensitivity of 75%, a specificity of 72%, and especially a very high negative predictive value with a value of 94.7%. This result is similar to other authors in the world [3]. The most commonly used IONM (Intraoperative Neurophysiological Monitoring) methods are SSEP and MEP. SSEP represents the activation of sensory pathway pathways and is stimulated by electrical stimulation of peripheral nerves such as the tibial nerve, and the median nerve. SSEP provides insight into the function of major fiber sensory pathways, from the peripheral nerves, through the dorsal root ganglia, posterior column, medial lemniscus, and thalamus, to the primary sensory cortex. In addition to serving as warning signs of mechanical trauma or ischemia of the dorsal column, they can be adversely affected by high doses of inhalational and intravenous anesthetics, as well as pre-existing neuropathy, such as diabetic radiculopathy or polyneuropathy.

Studies have documented post-operative motor deficits despite no change in intraoperative SSEP [13,14]. Somatosensory-evoked potentials were the first technique used to monitor spinal cord function during spinal surgery. It was thought that any conduction block in sensory pathways in patients with intramedullary tumors would also reflect similar conduction blocks in the corticospinal pathways. However, spinal cord injury is not always uniform during intramedullary spinal cord tumor removal surgery. As the SSEP pathway involves the posterior column of the spinal cord, it is not possible to monitor motor function when intramedullary maneuvers cause cord injury only to the motor tracts; this limitation has previously been reported in patients undergoing surgery for intramedullary spinal cord tumor [15,16].

In this study, we found that MEP has a very high sensitivity of 100%, a specificity of 80%, and a negative predictive value of 100%. This result is similar to other studies in the world [3]. This highly sensitive MEP helps alert the surgeon early, preventing irreversible nerve damage. MEP assesses the continuity of action potentials from the primary motor cortex through the pyramid tract to anterior horn cells, ventral nerve roots, peripheral nerves, neuromuscular junctions, and muscles. For stimulation, scalp electrodes stimulate the motor cortex through the skin. Short sequences of electrical stimulation spaced apart are delivered through scalp electrodes. Changes in wave strength or loss may allow the surgeon to take corrective measures to prevent functional defects. Limitations include the intermittent nature of recordings (compared to the long-term average in SSEP) and increased patient movement with higher concentrations of inhaled anesthetic and the unreliability of using neuromuscular blocking [5,17]. Diagnostic systems of several kinds are used to distinguish between two data of events, essentially "signals" and "noise." For them, analysis in terms of the "relative operating characteristic" of signal detection theory provides a precise and valid measure of diagnostic accuracy. It is the only measure available that is uninfluenced by decision biases and prior probabilities, and it places the performances of diverse systems on a common, easily interpreted scale [18,19].

The limitations of the study are that it is not a prospective study design, and mistakes can be made when selecting a sample. In addition, at our facility, we do not have a D-wave monitoring electrode, although this technique has proven to play a role in other studies around the world [15,20].

Conclusion

MEP and SSEP have high sensitivity of 100% and 75%, respectively, in detecting postoperative neurological defects, helping to predict and prevent timely nerve damage during intramedullary tumor removal surgery. In the absence of intraoperative neurophysiological monitoring, neurologic complications of intramedullary spinal cord removal surgery are often high. The introduction of SSEP and MEP changed this picture dramatically and today we can rely on a very reliable combined SSEP-MEP IOM strategy. In our opinion, the combination of MEP and SSEP supports a more aggressive surgery in an attempt to completely remove the tumor. What needs to be clearly considered is the value of IOM in patients presenting for surgery with severe neurological deficits and the role that IOM plays in different tumor types such as ependymomas, astrocytoma's, and hemangioblastomas. In the future, it is necessary to have prospective studies on the association of SSEP, MEP, and D-wave with intraoperative nerve damage in order to standardize these techniques in the world.

References

1. Kumar R, Banerjee S. Management and functional outcome of intramedullary spinal cord tumors: A prospective clinical study. Asian J Neurosurg. 2014;9(4):177-81.
2. Sandalcioglu IE, Gasser T, Asgari S, Lazorisak A, Engelhorn T, Egelhof T, et al. Functional outcome after surgical treatment of intramedullary spinal cord tumors: Experience with 78 patients. Spinal Cord. 2005;43(1):34-41.
3. Azad TD, Pendharkar AV, Nguyen V, Pan J, Connolly ID, Veeravagu A, et al. Diagnostic utility of intraoperative neurophysiological monitoring for intramedullary spinal cord tumors: Systematic review and meta-analysis. Clin Spine Surg. 2018;31(3):112-9.
4. Boström A, Hans FJ, Reinacher PC, Krings T, Bürgel U, Gilsbach JM, et al. Intramedullary hemangioblastomas: Timing of surgery, microsurgical technique and follow-up in 23 patients. Eur Spine J. 2008;17(6):882-6.
5. Paradiso G, Lee GYF, Sarjeant R, Hoang L, Massicotte EM, Fehlings MG. Multimodality intraoperative neurophysiologic monitoring findings during surgery for adult tethered cord syndrome: Analysis of a series of 44 patients with long-term follow-up. Spine (Phila Pa 1976). 2006;31(18):2095-102.
6. Ebner FH, Roser F, Falk M, Hermann S, Honegger J, Tatagiba M. Management of intramedullary spinal cord lesions: Interdependence of the longitudinal extension of the lesion and the functional outcome. Eur Spine J. 2010;19(4):665-9.
7. Eroes CA, Zausinger S, Kreth FW, Goldbrunner R, Tonn JC. Intramedullary low-grade astrocytoma and ependymoma. Surgical results and predicting factors for clinical outcome. Acta Neurochir (Wien). 2010;152(4):611-8.
8. Sun J, Wang Z, Li Z, Liu B. Microsurgical treatment and functional outcomes of multi-segment intramedullary spinal cord tumors. J Clin Neurosci. 2009;16(5):666-71.
9. Liang JT, Bao YH, Zhang HQ, Huo LR, Wang ZY, Ling F. Management and prognosis of symptomatic patients with intramedullary spinal cord cavernoma. Clinical article. J Neurosurg Spine. 2011;15(4):447-56.
10. Klekamp J. Treatment of intramedullary tumors: Analysis of surgical morbidity and long-term results. J Neurosurg Spine. 2013;19(1):12-26.
11. Jin SH, Chung CK, Kim CH, Choi YD, Kwak G, Kim BE. Multimodal intraoperative monitoring during intramedullary spinal cord tumor surgery. Acta Neurochir. 2015;157(12):2149-55.
12. Muramoto A, Imagama S, Ito Z, Ando K, Tauchi R, Matsumoto T, et al. The cutoff amplitude of transcranial motor evoked potentials for transient postoperative motor deficits in intramedullary spinal cord tumor surgery. Spine (Phila Pa 1976). 2014;39(18):E1086-94.
13. Kothbauer K, Deletis V, Epstein FJ. Intraoperative spinal cord monitoring for intramedullary surgery: An essential adjunct. Pediatr Neurosurg. 1997;26(5):247-54.
14. Kobayashi S, Matsuyama Y, Shinomiya K, Kawabata S, Ando M, Kanchiku T, et al. A new alarm point of transcranial electrical stimulation motor evoked potentials for intraoperative spinal cord monitoring: A prospective multicenter study from the spinal cord monitoring working group of the Japanese society for spine surgery and related research. J Neurosurg Spine. 2014;20(1):102-7.
15. Sala F, Bricolo A, Faccioli F, Lanteri P, Gerosa M. Surgery for intramedullary spinal cord tumors: the role of intraoperative (neurophysiological) monitoring. Eur Spine J: Official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2007;16(Suppl 2):S130-9.
16. Ando M, Tamaki T, Yoshida M, Kawakami M, Kubota S, Nakagawa Y, et al. Intraoperative spinal cord monitoring using combined motor and sensory evoked potentials recorded from the spinal cord during surgery for intramedullary spinal cord tumor. Clin Neurol Neurosurg. 2015;133:18-23.
17. Nguyen V, Lopez JR. Neuromonitoring. EMG, SSEP and MEP. In: Nader R, Berta SC, Gragnaniello G, Sabbagh AJ, Levy ML, editors. Neurosurgery tricks of the trade: Spine and peripheral nerves. New York: Thieme; 2014. p. 404-9.
18. Velayutham P, Rajshekhar V, Chacko AG, Babu SK. Influence of tumor location and other variables on predictive value of intraoperative motor evoked potentials in spinal cord tumor surgery. World Neurosurg. 2016;92:264-72.
19. Swets JA. Measuring the accuracy of diagnostic systems. Science. 1988;240(4857):1285-93.
20. Fischer G, Brotchi J. Intramedullary spinal cord tumors. Stuttgart, Germany: Thieme; 1996.