DOI:10.4274/tnd.93798

Original Article / Özgün Araştırma

Intraoperative Neurophysiological Monitoring to Prevent New Neurological Deficits in Spinal Tumor Cases

İntraoperatif Nöromonitörleme ile Spinal Tümör Cerrahisinde Yeni Defisit Gelişiminin Önlenmesi

Elif Ilgaz Aydınlar[1], Pınar Yalınay Dikmen[1], Gökalp Sılav[2], Mehmet Zafer Berkman[3], İlhan Elmacı[2], Serdar Özgen[2]

[1]Acıbadem University School of Medicine, Department of Neurology, Istanbul, Turkey
[2]Acıbadem University School of Medicine, Department of Neurosurgery, Istanbul, Turkey
[3]Acıbadem Maslak Hospital, Department of Neurosurgery, Istanbul, Turkey

Summary

Objective: Intraoperative neurophysiological monitoring was carried out in patients with spinal cord tumors. These patients were retrospectively evaluated for new postoperative neurological deficits.

Materials and Methods: A total of 32 spinal tumor cases (8 cervical, 14 thoracic, 10 lumbosacral), 17 male and 15 female, patients between 2-66 years of age (mean 44.1±20) operated in our center were evaluated. All of our cases were monitored with somatosensory evoked potentials (SEP) muscular motor evoked potentials (MEP) and free run electromyography. Spinal MEP (D wave), bulbocavernosus reflex (BCR) and pudendal SEP were obtained in appropriate cases.

Results: Five cases presented with temporary new postoperative neurological deficits in the form of strength loss. Neurophysiological recordings of all of these patients showed either temporary or permanent deterioration during surgery.The tumor was removed completely or almost completely in 26, near-completely in 4 and partially in 2 cases and none of our cases had a new permanent deficit.

Conclusion: The functional integrity of the lateral and dorsal columns of the spine can be assessed by SEP and muscular MEP recording. Additional information about the neurological tissue is given by spinal MEP, BCR and pudendal SEP in suitable cases. We did not experience any false positive or negative results in our cases and we believe that the combined use of intraoperative spinal and MEP in spinal column located tumors gives reliable information about postoperative neurological outcome. (Turkish Journal of Neurology 2014; 20:45-8)

Key Words: Intraoperative neurophysiological monitoring, spinal tumor, deficit

Özet

Amaç: Spinal tümör cerrahisi esnasında hastalara intraoperatif nöromonitörleme yaptık. Bu hastalarda postoperatif yeni nörolojik defisit gelişimini retrospektif olarak değerlendirdik.

Gereç ve Yöntem: Onyedisi erkek, 15'i kadın olmak üzere, 2-66 yaşlarında (ort 44±20) 32 spinal tümör hastası (8 servikal, 14 torakal ve 10 lumbosakral yerleşimli) değerlendirmeye alındı. Nöromonitörleme amacıyla bütün hastalar somatosensoriyel uyandırılmış potansiyeller (SEP), motor uyandırılmış potansiyeller (MEP) ve spontan elektromiyografi ile izlendi. Uygun vakalarda spinal MEP (D dalgası), bulbokavernöz refleksi (BKR) ve pudendal SEP elde edildi.

Bulgular: Beş vakada ameliyat sonrası geçici güç kaybı izlendi. Bu hastaların tümünde ameliyat esnasında nöromonitörleme bulgularında kalıcı ya da geçici değişiklikler dikkati çekti. Hiçbir vakada kalıcı güç kaybı görülmezken, 26 hastada tümör total ya da totale yakın, 4 hastada subtotal ve 2 hastada da parsiyel olarak eksize edildi.

Sonuç: Medulla spinalisin lateral ve dorsal kolonların fonksiyonel bütünlüğü SEP ve müsküler MEP ile takip edilebilir. Uygun vakalarda spinal MEP, BKR ve pudendal SEP ile nöral dokular hakkında ilave bilgi elde etmek mümkündür. Vakalarımızda yanlış pozitif ve negatif sonuç ile karşılaşmadık. Spinal tümörlerde intraoperatif SEP ve MEP'in kombine kullanımı ile hastanın postoperatif nörolojik durumu hakkında güvenilir bilgi elde edilebileceğini düşünmekteyiz. (Türk Nöroloji Dergisi 2014; 20:45-8)

Anahtar Kelimeler: Intraoperatif nöromonitörleme, spinal tümör, defisit

Address for Correspondence/Yazışma Adresi: Elif Ilgaz Aydınlar MD, Acıbadem University School of Medicine, Department of Neurology, Istanbul, Turkey
Phone: +90 212 304 44 55 E-mail: ilgaz2000@yahoo.com
Received/Geliş Tarihi: 21.02.2014 **Accepted/Kabul Tarihi:** 13.03.2014

Introduction

The first documented successful attempt at intramedullar tumor surgery was performed by the Vienna University Chair of Surgery, Prof. Dr. Eiselsberg in 1907 (1). Despite the advancement in the surgical techniques, the spinal cord attempts had a high mortality reaching up to 3.7%-7.7% by the end of 20th Century (2,3). In the past twenty years, intraoperative neuromonitoring (IONM) has become a routine application in most centers for enabling the surgeon to perform the tumor resection more safely and for minimizing the development of postoperative deficits in the spinal tumor cases. In this study, we retrospectively evaluated the development of new postoperative deficits in our past patients who had undergone spinal tumor surgery with IONM.

Methods

Thirty two spinal tumor patient (17 male, 15 female; 8 cervical, 14 thoracic and 10 lumbosacral) were included in the evaluation.

Anesthesia

The patients underwent total anesthesia through intravenous use of propofol (8 mg/kg per hour in average) and remifentanil (0.2 µg/kg per minute). One MAC sevoflurane were given instead of muscle relaxant during intubation. During the preoperative stage, 0.1-0.15 mg/kg morphine HCL was used as an analgesic.

Intraoperative Neuromonitoring

All of our patients were monitored continuously during their procedure by using somatosensory evoked potentials (SEP) (Table 1), motor evoked potentials (MEP) (Table 2) and continuous electromyography. In the suitable cases, spinal MEP (D wave), bulbocavernosus reflex and pudendal SEP were also used.

After the general anesthesia induction, one or two rolls of gauze pads were placed in the patients' mouth to protect the tongue from being bit.

Table 1. Intraoperative SEP monitoring
Stimulation: Median or ulnar nerves
Posterior tibial nerves
Recording: C3'- FZ and C4'- FZ
Cz'-FZ
Stimulus duration: 0.2 -0.5ms
Filter setting: 30-3000 Hz
Averaging: 200-300
Frequency: 5 Hz

Table 2. Intraoperative muscle MEP monitoring
Stimulation: C1-C2, C3-C4
Recording: Extremity muscles
Stimulus duration: 0.5ms
Interstimulus interval: 2-4ms
Filter setting: 20-2000 Hz
Frequency: 2-3 Hz

Transcranial stimulations were performed using subcutaneously placed screw electrodes (Ambu 74715-60/24) on the C1, C2, C3 and C4 localizations according to the international 10-20 system. For the stimulation of the left hemisphere, C1 (anode), C2 (cathode), C3 (anode), C4 (cathode); for the right hemisphere C2 (anode), C1 (cathode), C4 (anode), C3 (cathode) were used. For muscle MEP a successive stimulation with 0.5 ms duration and 4 ms interstimulus interval and for spinal MEP a single-shot stimulation of 0.5 ms duration was used. Muscle MEP was acquired by placing the twisted disposable needle electrodes (Ambu 74612-200/1/2) on the appropriate muscles. The spinal MEP (D wave) recordings in the cervical and thoracic tumors were made by using 3 platinum contact electrodes (Adtech CEDL-3PDINX).

For the somatosensorial recordings, ulnar nerve on the upper extremities and posterior tibial nerves on the lower extremities were stimulated with bar electrodes (Viasys 019-401400) using 0.5 ms stimulus duration. The recordings were made from the cortex on C3-Fz and C4-Fz for the upper extremities and Cz-Fz for lower extremities.

For the acquisition of bulbocavernosus (BCR) reflex, adhesive electrodes (Carefusion 019-420800) were placed either at the dorsum penis or clitoris to stimulate, and the needle electrodes were placed on the both anal sphincters for recording. Similarly, the cathodes of the adhesive electrodes were placed on dorsum penis and clitoris for the pudendal SEP, and recorded from Cz-Fz on the cortex using screw electrodes.

Muscle MEP recordings were acquired in alternation with SEP and D wave recordings. Based on the previously published findings (4-6) alarm criteria were defined as a 50% decrease in SEP amplitude, 10% increase in latency, total loss of muscle MEP or the doubling of the stimulation threshold, and 30% or more decrease in the spinal MEP (D wave) amplitude.

Table 3. Pathology distribution

	n
Intramedullary tumors	
Ependymoma	6
Astrocytoma	5
Cavernoma	2
Hemangioma	1
Extramedullary tumors	
Schwannoma	7
Meningioma	5
Metastasis	1
Other	
Arterivenous malformation	2
Dermoidal cyst	1
Chordoma	1
Ganglion cyst	1
Total	32

Results

The patients' ages ranged between 2 and 66 (mean 44.1±20). Tumor placement was intramedullary in 14 cases, extramedullar in 13 cases and extradural in 5 cases (Table 3). The pathological diagnoses were listed in Table 3. Tumor was excised gross-totally in 23 patients (71.8%), nearly totally in 3 (9.3%), subtotally in 4 (12.5%), and partially in 2 patients (6.25%). The postoperative neurological state was assessed during discharge and 1 month after the surgery. In the first postoperative day, 2 patients (patient 4 and 5) (6.25%) described additional loss of strength compared to preoperative state, 2 patients (patient 1 and 2) (6.25%) also described loss of strength, and patient 3 showed hypoesthesia on the right arm (Table 4). Four of the progressive or acquired paresis patients (12.5%) showed recovery during discharge and one showed recovery (patient 2) (3.1%) a month after discharge.

Discussion

The use of IONM in intradural and intramedullary tumor surgeries has recently become a common practice (7). However, the intramedullary spinal lesions monitored only with SEP tend to give false positive results (8-10). While SEP provides reliable information about the function of medulla spinalis' dorsal colon, the integrity of the lateral colons is only possible with MEP. In all of the cases in our clinic, IONM was conducted multimodally, that is by combining SEP and MEP. In addition, BCR and pudendal SEP were also included in the monitoring protocol in order to assess pudendal pathways.

Class 1 randomized prospective studies investigating the efficiency of IONM in preventing new neurological deficits are unfortunately impossible due to ethical and medicolegal considerations. For that reason, it is possible to come across publications from the same medical team in an institution detailing the procedures made with or without IONM. These studies indicate that patients who were monitored with IONM show more favorable long-term motor results (11,12). In our study, we also retrospectively evaluated our patients and conclude that their neurological state after 1 month is different than the preoperative stage and in fact improved for the second patient.

Perturbations in the IONM data stream are often seen during the moment of resection of the tumor (13). All of our patients who

Table 4. Neurophysiological changes during the surgery and postoperative deficits

Patient	Age/sex	Lesion location	IONM* changes	Preoperative deficit level	New postoperative deficit	Tumor resection amount
1	66/K	Cervical extramedullary	Temporary loss in lower left extremity muscle †MEP and permanent decrease in D wave amplitude by 30%	Quadriparesis	Visible increase in lower left paresis	Total
2	2/K	Thoracic intramedullary	Temporary loss in lower and upper left extremities muscle MEP, permanent loss in lower right muscle MEP and permanent decrease in D wave amplitude by 30%	Paraparesis in the lower extremities	Visible increase in lower right paresis	Subtotal
3	33/E	Cervical intramedullary	Permanent loss in bilateral upper extremity ‡SEP, temporary loss in upper left MEP, temporary decrease in D wave amplitude by 30%	Left frust hemiparesis	Hypoesthesia in right arm	Near total
4	33/E	Cervical extramedullary	Temporary loss in lower right extremity muscle MEP	None	Loss of strength in lower right extremity	Total
5	63/E	Thoracic intramedullary	Temporary loss in lower left extremity muscle MEP and permanent loss in SEP amplitude by 50%	None	Loss of strength in lower right extremity	Total

*IONM: Intraoperative neuromonitoring, † MEP: Motor evoked potentials, ‡SEP: Somatosensorial evoked potential.

showed IONM changes and suffered from postoperative loss of strength had some distortions in the data stream especially during the resection of the tumor. In one of our patients, the resection procedure was terminated due to the loss of muscle MEP and the operation was completed with subtotal excision (Patient 2, Table 4). Generally, we recommend that surgical procedure should be halted when a change in the IONM data stream was observed, after ruling out a possible equipment malfunction. The surgeon should make changes on the resection procedure.

Spinal MEP (D wave) can be acquired through transcortical stimulation by targeting wide radius corticospinal axons with a special catheter. D wave amplitude decrease is equivalent to the loss of functional axons in the same amount. Morota et al. reported that such recordings yield reliable results in intramedullary surgery (14).

In our study 17 patients were implanted with epidural electrodes and D waves were acquired from 14 patients. D wave amplitude decreased temporarily in one patient but it returned back to its original level by the end of the operation. In two patients, the loss of amplitude remained unchanged until the end of the operation (Table 4). Szelenyi et al. expressed that the combination of S100B, a serum marker that indicates glial damage, and evoked potentials can provide a good estimation of the spinal cord damage (15).

Sala et al., suggested that even though muscle MEP is lost during the surgery while D wave remains at least in its half amplitude, the motor deficits due to surgery would be transient and therefore the operation should be completed (12). We also made the decision to complete the operation in a patient who had loss muscle MEP during surgery with D wave amplitude decreasing only by 30% (Table 4). The postoperative loss of strength in the lower left extremity was restored to its preoperative levels during discharge.

It is recommended that IONM is conducted not only during tumor resection but following the moment of first incision until the operation is completed. The literature also shows that the early stages of the surgery involve 18%-34.6% changes in the IONM data (12,16,17). In our series, we did not observe transient or permanent IONM changes in the early stages of the surgeries. The intraoperative monitoring of BCR is recommended especially to monitor the integrity of lower sacral sensory and motor tissues. The loss of BCR during the operation indicates damage to the lower sacral segments (18). In our study, 4 patients had BCR monitoring; the unilateral potential seen in one patient at the beginning of the surgery disappeared during the operation without recovery. This patient's previous complaints about urge incontinence, however, did not worsen after the operation.

We did not encounter a false positive in our study and based on our findings we propose that multimodal monitoring using SEP and MEP in spinal tumor surgery can prevent surgically-induced neurological complications such as paraparesis, paraplegia and quadriplegia while allowing the surgeon adequate time to make adjustments in the surgical procedure.

References

1. Eiselsberg A, Strümpell A. Wien Med Wochenschr 1910;11:648-649.
2. Epstein NE, Danto J, Nardi D. Evaluation of intraoperative somatosensory-evoked potential monitoring during 100 cervical operations. Spine (Phila Pa 1976) 1993;18:737-747.
3. Zentner J. Motor evoked potential monitoring during neurosurgical operations on the spinal cord. Neurosurg Rev 1991;14:29-36.
4. Deletis V. Intraoperative monitoring of the functional integrity of thr motor pathways, in Devinsky O, beric A, Dogali M (eds): Electrical and Magnetic stimulation of the Brain and spinal cord. New York, Raven Press 1993;201-214.
5. Kothbauer K, Deletis V, Epstein FJ. Intraoperative spinal cord monitoring for intramedullary surgery: An essential adjuct. Pediatr Neurosurg 1997;26:247-254.
6. Sala F, Lanteri P, Bricolo A. Motor evoked potential monitoring for spinal cord and brain stem surgery. Adv Tech Stand Neurosurg 2004;29:133-169.
7. Gonzalez AA, Jeyanandarajan D, Hansen C, Zada G, Hsieh PC. Intraoperative neurophysiological monitoring during spine surgery; a review. Neurosurg Focus 2009;27:E6
8. Lesser RP, Raudzens P, Lüders H, Nuwer MR, Goldie WD, Morris HH 3rd, Dinner DS, Klem G, Hahn JF, Shetter AG, et al. Postoperative neurological deficits may occur despite unchanged intraoperative somatosensory evoked potentials. Ann Neurol 1986;19:22-25.
9. Ginsburg HH, Shetter AG, Raudzens PA. Poststoperative paraplegia with preserved intraoperative somatosensory evoked potentials. Case report. J Neurosurg 1985;63:296-300.
10. Wiedemayer H, Sandalcioglu IE, Armbruster W, Regel J, Schaefer H, Stolke D. False negative findingsin intraoperative SEP monitoring: analysis of 658 consecutive neurosurgical cases and review of published reports. J Neurol Neurosurg Psychiatry 2004;75:280-286.
11. Harner SG, Daube JR, Ebersold MJ, Beatty CW. Improved preservation of facial nerve function with use of electrical monitoring during removal of acoustic neuromas. Mayo Clin Proc 1987;62:92-102.
12. Sala F, Palandri G, Basso E, Lanteri P, Deletis V, Faccioli F, Bricolo A. Motor evoked potential monitoring improves outcome after surgery for intramedullary spinal cord tumors: a historical control study. Neurosurgery 2006;58:1129-1143
13. Forster MT, Marquardt G, Seifert V, Szelenyi A. Spinal cord tumor surgery--importance of continuous intraoperative neurophysiological monitoring after tumor resection. Spine (Phila Pa 1976) 2012;37:E1001-1008.
14. Morota N, Deletis V, Constantini S, Kofler M, Cohen H, Epstein FJ. The role of motor evoked potentials during surgery for intramedullary spinal cord tumors. Neurosurgery 1997;41:1327-1336.
15. Szelényi A, Heukamp C, Seifert V, Marquardt GS. 100B, intraoperative neuromonitoring findings and their relation to clinical outcome in surgically treated intradural spinal lesions. Acta Neurochir (Wien) 2014;156:733-739.
16. Garcés-Ambrossi GL, McGirt MJ, Mehta VA, Sciubba DM, Witham TF, Bydon A, Wolinksy JP, Jallo GI, Gokaslan ZL. Factors associated with progression-free survival and long-term neurological outcome after resection of intramedullary spinal cord tumors: analysis of 101 consecutive cases. J Neurosurg Spine 2009;11:591-599
17. Jenkinson MD, Simpson C, Nicholas RS, Miles J, Findlay GF, Pigott TJ. Outcome predictors and complications in the management of intradural spinal tumours. Eur Spine J 2006;15:203-210.
18. Deletis V, Vodusek DB. Intraoperative recording of the bulbocavernousus reflex. Neurosurgery 1997;40:88-93.