# SPINAL CORD MONITORING OF PATIENTS WITH NEUROLOGICAL DEFICITS

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*Intraoperative monitoring of spinal cord function is a useful tool to decrease the potential risk of neural damage particularly in intradural and intramendullay surgery. However, most of the experience on spinal cord monitoring in the literature is a collection of the cases without neurological deficits and with relative low risk of morbidity. It seems very difgicult to make a reliable monitoring of the cases with neurological deficits and preoperative evoked potential abnormalities.*

*This is a report of our first experience with spinal cord monitoring on 9 patients (2 intradural tumors, 1 intramedullary tumor, 1 clivus tumor, 3 tethered cord syndrome, 1 cervical spondylotic myelopathy). Cortical and intradural spinal somatosensory evoked potentials after stimulation of tibial and median nerves were monitored in all cases.*

*7 cases showed good correlation with evoked potential changes. There were 1 false-positivity and 1 falsenegativity. In one case with lipomeningocel, stimulation of the spinal cord gave useful information in identifying functional tissue from nonfunctional part.*

*We experienced some pitfalls, which should be adressed to offer reliable information to the surgeon. An appropriate selection and combination of evoked potentials is an important factor to carry out effective spinal cord monitoring especially the cases with neurological deficits.*

## INTRODUCTION

Electrophysiologic monitoring of the spinal cord with somatosensory evoked potentials to provide secure guidelines for the surgeon of the functional integrity of the spinal cord level under consideration during risky operations were first introduced in 1971 by Nash et al (20). Afterwards it has widely been used mostly by orthopaedic surgeons as an additive or more reliable test to wake-up test (1, 3, 4, 5, 6, 8, 10, 11, 16, 18, 19, 25, 27). Recently, a cumulative data of approximately 60.000 cases were collected as a survey of the Scoliosis Research Society (SRS) and the European Spinal Deformity Society (ESDS) membership. The results of this survey was published (9) and discussed in The Fifth International Symposium On Spinal Cord Monitoring held on June 1992 in London.

Among 60.366 cases, there were 1.002 false-positivity, 263 true-positivity and 101 false-negativity. SEP monitoring was correctly predicted a postoperative deficit 72 % of the time one was present (9).

Neurosurgical operations on the spine does however include mostly the cases with neurologic deficits and preoperative SEP abnormalities (15, 23, 24, 26, 27, 30). Intraoperative monitoring of the spinal cord with some sort of conduction block has peculiar difficulties and it is impossible to monitor the cases with no detectable SEPs 523).

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This study discusses the monitoring problems of some neurosurgical cases with special emphasis on abnormal SEPs due to neurological deficits.

## MATERIAL AND METHOD

This study was done on 9 patients operated on for different spinal cord lesions in The Department of Neurosurgery, Ege University Faculty of Medicine, İzmir, Turkey. 2 patients had intradural tumors, 1 intramedullary tumor, 1 clivus tumor, 3 tethered cord syndrome, 1 cervical spondylotic myelopathy. All but one case with tethered cord syndrome had preoperative neurological deficits. Cortical and intradural spinal somatosensory evoked potentials after stimulation of tibial and median nerves were monitored in all cases. Al lpatients have had a detailed neurological examination with greater emphasis on sensory deficits. A preoperative SEP examination was done a few days before th eoperations. All patients had a postoperative SEP examination mostly one week after the operation.

Pre-and postoperative SEPs included posterior tibial and median nerve stimulations seperately. tibial SEPs (tSEP) were recorded from L1, C2, and Cz with Fpz reference according to 10-20 EEG recording system and leg grounds. 100 ms analysis time was used. Posterior tibial nerve was stimulated at medial ankle at 3.2 Hz stimulus frequency with submaximal intensities. Median SEPs (mSEP) were recorded from C2, and C3' or C4' with Fpz reference. 50 ms analysis time was used. Median nerve was stimulated at wrist and

3.2 Hz stimulus frequency with submaximal intensities were used. subdermal needles were chosen for recording in all recording sites and impedances were lowered below 5 KOhm for optimal recording. Sensitivity was setup as 20 µV/division.

Intraoperative recordings were done from the same preoperative sites. After approaching the operative site, intradural (7 cases) or extradural (2 cases; 1 clivus tumor, 1 cervical spondylotic myelopathy) fine tipped platinum monopolar recording electrodes (Medelec Company, United Kingdom) were inserted and cord potentials in addition to cortical potentials were monitored. The needle electrodes from spinal levels were cancelled during this period. Automatic artefact rejection was routinely used. All recordings were done with a two-channels EP unit (Phasis, ESAOTA Company, Italy) which has on-line analysis and disc storage facilities. The data acquisition was ceased during usage of monopolar cothers.

An amplitude decrease more than 50 % and latency increase more than 3 ms were accepted as warning limits.

## RESULTS:

A reliable monitoring could ble done in all cases. Other than expected artefact rejection problems during monopolar cotherization, no other technical problems were observed.

4 cases showed no SEP changes, and no neurological detorioration occured (True negativity). But one of them (#9; 62 years old woman, foramen magnum neurionoma) has developed a delayed central cord syndrome, although she had no additional neurological deficits in the early postoperative period (Table 1).

3 cases showed significant SEP changes during monitoring and they developed some degree of neurological deterioration (True positivity) (Figure 1). 1 case (#7; 4 years old male, T8-9 intramedullary dermoid cyst) had significant SEP changes, but there was no neurological deficits postoperatively (False positivity).

1 case (#5; 13 years old male, tethered cord syndrome due to lumbosacral lipomeningocel) had no changes during tibial SEP monitoring, but developed urinary incontinence postoperatively (False negativity).

In one case (#2; 11 years old female) during excision of a lumbosacral meningocel, stimulation of distal stupf was found to be useful in identifying functional tissue from nonfunctional tissue (Figure 2).

## DISCUSSION:

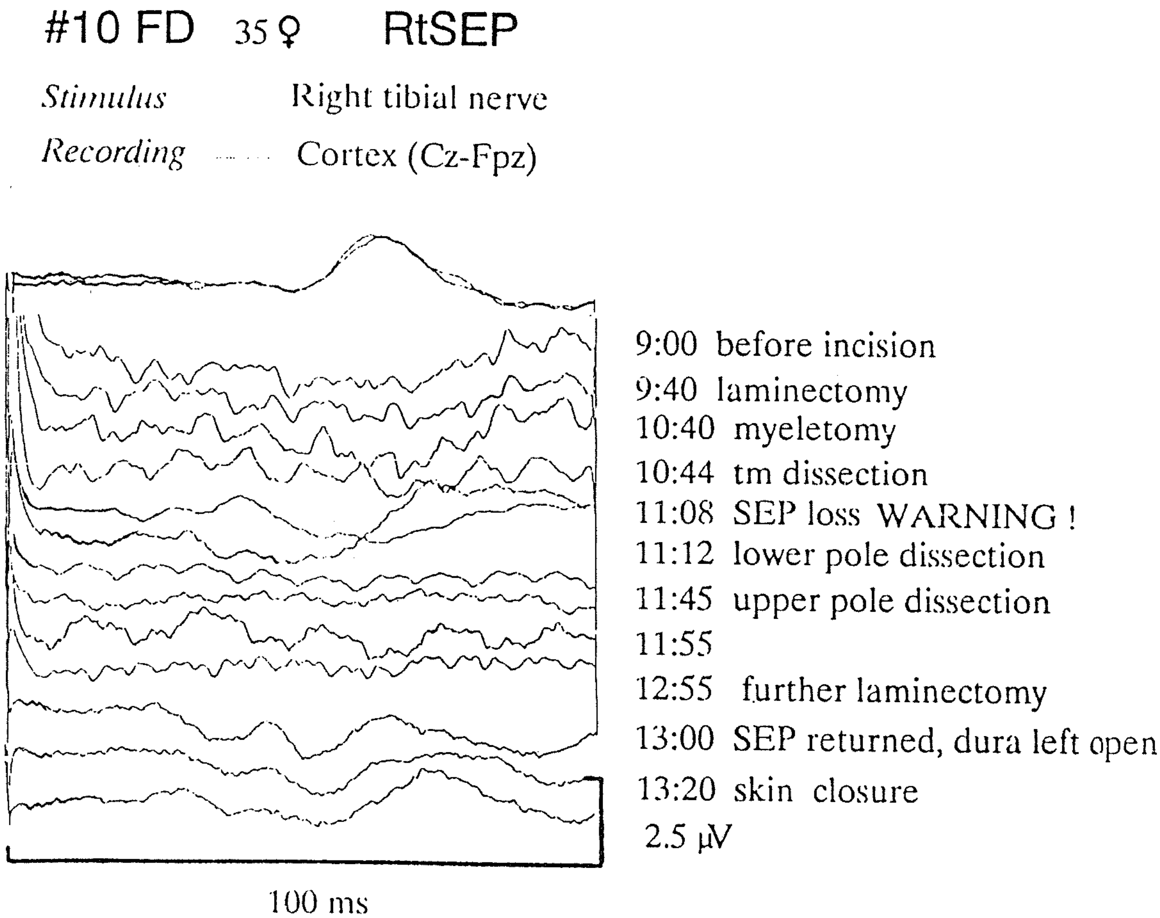
It is said that to conduct some form of monitoring when performing any spinal operation that is associated with a high risk of neurologic injury is a standart practice of today (19).

In general the percent of false positivities are more than false negativities (9, 23). False positivity is not dangerous for patient. But it causes a stress to the spine surgeon. In contrast to false positivity, false negativity may be very harmful for the patient and may cause an unnecesessarily radical operation. Although it

**Table 1:** Summary of cases. (Deter. = Deterioration; no = no change; mSEP = median somatosensory evoked potential; tSEP tibial somatosensory evoked potential; BAEP = brainstem auditory evoked potential)

| # Initial | Age Sex | Diagnosis | Monitoring Modality | EP changes | Nreurol. deficit | Comment |
|---|---|---|---|---|---|---|
| 1 RÇ | 40 M | Chordoma of the clivus | mSEP, BAEP | Deter. | Deter. | True (+) |
| 2 ZG | 11 F | Tethered cord (Lipomeningocel) | tSEP | Deter. | Deter. | True (+) |
| 3 BÖ | 53 M | C2-3 neurinoma | mSEP, tSEP | no | no | True (–) |
| 4 ÖA | 9 F | Tethered cord (tight filum) | tSEP | no | no | True (–) |
| 5 Hİ | 13 M | Tethered cord (lipomeningocel) | tSEP | no | Deter. | False (–?) |
| 6 FD | 35 F | Cervical intramedullary tumor | mSEP, tSEP | Deter. | Deter. | True (+) |
| 7 HT | 4 M | T8-9 intramedullary tumor | tSEP | Deter. | no | False (+) |
| 8 RA | 58 M | Cervical spondylotic myelopathy | mSEP, tSEP | no | no | True (–) |
| 9 MC | 62 F | Neurinoma of foramen magnum | mSEP, tSEP | no | (delayed deficit) | True (–) |

**Figure 1:** Intradural cercival cord potentials during operation of a cericobulbar intramedullary astrocytoma. During lower pole dissection of the tumor, cortical SEPs to tibial nerve stimulation were lost, and a more than 50 % amplitude decrease in cord potentials has occured (5th trace from above). A significant deterioration in motor and sensory deficits was observed postoperatively (True positive result).




is not as frequent as false positivity, it is very important for the reliability of the monitoring. The general reasons for false negativity are:

a) the lack of information about anterior spinal cord function during monitoring only with SEPs,

b) choosing just one parameter (latency or amplitude) as alarm criteria.

One of our cases has false negativity. But we may say that the reason for that false response is insufficient monitoring, since tibial SEPs are not capable of showing sphincter innervation (S2-S4) which was damaged during operation in this case.

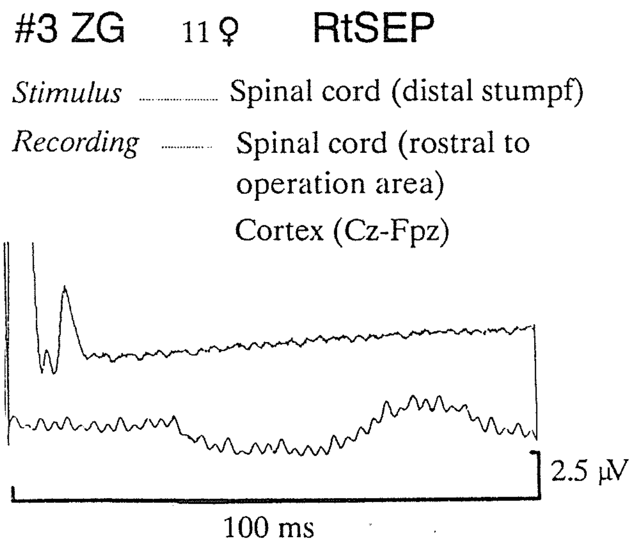
For those reasons, the unwanted false negativities could be prohibited by; 1) monitoring motor evoked potentials in addition to SEPs (3, 8, 17, 28, 29, 30); 2) choosing alarm criteria with both amplitude and latency monitoring; 3) penil and/or urethral evoked potentials monitoring during lumbosacral cord surgery (7).

The insufficiency of SEP monitoring for showing the cord function in to was shown by different workers (4, 8, 14). The new developed motor evoked potential (MEP) monitoring techniques with noninvasive transcranial stimulators seems to be promising to solve this problem (30).

The number of cases in this series is not sufficient to draw precise conclusions about the cases with neurological deficits. But the number of problems (total number of true positive + false positive = false negative cases) during monitoring of those cases with neurological deficits seems to be much higher than most orthopedic series who has not these properties (9).

One of the future prospects of spinal cord monitor-

**Figure 2:** Druing excision of a lipomeningocel, cortical (lower trace) and spinal cord (upper trace) potentials in response to bipolar stimulation showed a functional neural tissue. Another stumpf in similar stimulation adn recording conditions gave, however no response, and a secure excision was performed.




ing should be to collect another survey incorporating monitoring cases with neurological deficits. The greatest limitation to collect such a survey might be the big variability in monitoring methods. Cortical, spinal surface, epidural, intradural recordings; peripheral nerve, spinal cord, motor cortex stimulations are used in a variety of stimulation and recording parameters (9, 10, 11, 21, 22, 25, 25, 26). The alarm criteria chosen by different centres are also not standardized (2, 9, 23, 24, 25, 27).

## REFERENCES

1. Albanese SA, Spadaro JA, Lubicky JP, Henderson NA. Somatosensory cortical evoked potential changes after deformity correction. Spine (Suppl) 16: S371-S374, 1991.
2. Allen A., Starr A., Nudleman K. Assessment of sensory function in the operating room utilizing cerebral evoked potentials; a study of fifty-six surgically anesthetised patients. Clin Neurosurg 28:457-481, 1981.
3. Aminoff MJ. Intraoperative monitoring by evoked potantials for spinal cord surgery: the cons. Electroenceph Clin Neurophysiol 73:378-380, 1989.
4. Apel DM, Marrero G, King J, Tolo VT, Bassett GS. Avoiding paraplegia during anterior spinal surgery: thew role of somatosensory evoked potential monitoring with temporary occlusion of segmental spinal arteries.
5. Brown RH., Nash JrCL. Implementation and evaluation of intraoperative somatosensory cortical potential procedures and pitfalls. in: Fundamentals and Clinical Application of Spinal Cord Monitoring. ed. by S.Homma, T.Tamaki, Saikon Publ., Co, Tokyo, 1984, pp.373-383.
6. Bunch WH., Scarff TB., Trimble J. Current concepts review: spinal cord monitoring. J Bone & Joint Surg 65:707-710, 1983.
7. Cohen BA, Major MR, Huizenga BA. Pudendal nerve evoked potential monitoring in procedures involving low sacral fixation. spine (Suppl) 16:S375-S377, 1991.
8. Daube JR. Intraoperative monitoring by evoked patentials for spinal cord surgery: the pros. Electroenceph Clin Neurophysiol 73:374-377, 1989.
9. Dawson EG, Sherman JE, Kanim LEA, Nuwer MC. Spinal cord monitoring: results of the scoliosis research society and the european spinal deformity society survey. Spine (Suppl) 16:S361-S364, 1991.
10. Deecke L, Tator CH. Neurophysiological assessment of afferent and efferent conduction in the injured spinal cord of monkeys. J Neurosurg 30:65-74, 1973.
11. Delwaide PJ, Delwaide C. Electrophyiological testing of human spinal cord. Neuro-Orthopedics 3:76-81, 1987.
12. Donaghy RMP, Numoto M. Prognostic significance of sensory evoked potential in spinal cord injury. Proc Spin Cord Inj Conf 17:251-257, 1969.
13. Ducker TB. Spinal cord neurophysiological monitoring during operation: A viewpoint. Neurosurgery 20:988, 1987.
14. Ginsburg HH., Shetter AG., Raudzens PA. Postoperative paraplegia with preserved intraoperative somatosensory evoked potentials -case report. J Neurosurg 63:296-300, 1985.
15. Grundy BL. Monitoring of sensory evoked potentials during neurosurgical operations: methods and applications. Neurosurg 11:556-575, 1982.
16. Han JF, Latchew JP. Evoked potentials in the operating room. in: Clinical Neurosurgery, Williams and Wilkins Co., Baltimore, London, vol 31, 1983, pp.389-403.
17. Levy WJ., York DH., McCaffrey M., Tanzer F.Motor evoked potentials from transcranial stimulation of the motor cortex in humans Neurosurg 15:287-302, 1984.
18. Macon JB., Poletti CE., Sweet WH., et al. Conducted somatosensory evoked potentials during spinal surgery. part 2: clinical applications. J Neurosurg 57:354-359, 1982.
19. Nash CL, Brown RH. Current concepts review: spinal cord monitoring. J Bone Jont Surg 71A:627-630, 1989.
20. Nash CL, Lorig RA, Schatzinger LA, Brown RH. Spinal cord monitoring during intraoperative treatment of the spine. Clin Orthop 12:100-105, 1977.
21. Nashold BS., Ovelen-Levitt J., Sharpe R., Higgins AC.

Intraoperative evoked potentials recorded in man directly from dorsal roots and spinal cord. J Neurosurg 62:680-693, 1985.
22. Raudzens PA. Intraoperative monitoring of evoked patentials. Ann NY Acad Sci 388:308-326, 1982.
23. Schramm J. Spinal cord monitoring: current status and new developments. in: Central Nervous System Trauma, Mary Ann Liebert Inc., vol 2, 3, 1985, pp.207-227.
24. Schramm J, Romstock J, Watanabe E, Cortical versus spinal recordings in intraoperative monitoring of space-occupying spinal lesions. in: Evoked Potentials III-The Third International Evoked Potentials Symposium. (edts) C Barber, T Blum. Butterworths, 1987, pp 328-334.
25. Shimoji K, Maruyama Y, Shimizu H, Fujioka H, Taga K. Spinal cord monitoring- ar review of current techniques and knowledge. in: Spinal Cord Monitoring. ed. J Schramm, SJ Jones. Springer- Verlag, Berlin, Heidemlberg, 16-28, 1985.
26. Watanabe E, Schramm J, Romstöck J. Cortical and spinal intraoperative recordings in uneventful monitoring and in cases with neurologic changes. In: Ducker TB, Brown RH (eds) Neurophysiology and Standarts of Spinal Cord Monitoring. Springer, Berlin, Heidelberg, New York (In Press)
27. Whittle IR., Johnston IH., Besser M. Recording of spinal somatosensory evoked potentials for intraoperative spinal cord monitoring. J Neurosurg 64:601-612, 1986.
28. Zentner J. Noninvasive motor evoked potential monitoring during neurosurgical operations on the spinal cord. Neurosurgery 24:709-712, 1989.
29. Zileli M, Schramm J. Motor versus somatosensory evoked potential changes after acute experimental spinal cord injury in rats. Acta Neurochir (Wien) 108:140-147, 1991.
30. Zileli M. Transcranial cortical stimuation and motor evoked potential applications in neurosurgery. in: Motor Evoked Potansiyeller. Edts C.Ertekin, M.Zileli, M.Ertaş, Klinik Nörofizyoloji Derneği Yayınları, 1992, pp 61-87.