Neuromonitoring for Intramedullary Spinal Cord Tumor Surgery

Terence Verla[1], Jared S. Fridley[1], Abdul Basit Khan[2], Rory R. Mayer[1], Ibrahim Omeis[1,3]

Key words
- Intramedullary tumor
- Spinal injury
- Intraoperative monitoring
- Outcomes

Abbreviations and Acronyms
DCM: Dorsal column mapping
EMG: Electromyography
IMSCT: Intramedullary spinal cord tumors
IONM: Intraoperative neuromonitoring
MAP: Mean arterial pressure
MEP: Motor evoked potential
SSEP: Somatosensory evoked potential
TcMEP: Transcranial motor evoked potential

From the [1]Department of Neurosurgery and [2]School of Medicine, Baylor College of Medicine, Houston, Texas, USA; and [3]Department of Surgery, American University of Beirut, Riad El-Solh, Beirut, Lebanon

To whom correspondence should be addressed:
Ibrahim Omeis, M.D.
[E-mail: Omeis@bcm.edu]

Citation: World Neurosurg. (2016) 95:108-116.
http://dx.doi.org/10.1016/j.wneu.2016.07.066

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

BACKGROUND: **Intramedullary spinal cord tumors (IMSCT) account for about 2%—4% of tumors of the central nervous system. Surgical resection continues to be the most effective treatment modality for most intramedullary tumors, with gross total resection leading to preserved neurologic function and improved survival. However, surgical treatment is often difficult and carries significant risk of postoperative neurologic complications. Intraoperative neuromonitoring has been shown to be of clinical importance in the surgical resection of IMSCT. The main monitoring modalities include somatosensory evoked potentials, transcranial motor evoked potentials via limb muscles or spinal epidural space (D-waves), and dorsal column mapping. These monitoring modalities have been shown to inform surgeons intraoperatively and in many cases, have led to alterations in operative decision.**

METHODS: **We reviewed the literature on the usefulness of intraoperative neuromonitoring for intramedullary spinal tumor resection and its role in predicting postoperative neurologic deficits. A MEDLINE search was performed (2000—2015) and 13 studies were reviewed. Detailed information and data from the selected articles were assessed and compiled. Data were extracted showing the role of monitoring in outcomes of surgery.**

CONCLUSIONS: **By using intraoperative somatosensory evoked potentials, transcranial motor evoked potentials, D-waves, and dorsal column mapping, spinal injury could be prevented in most cases, thereby improving postoperative neurologic functioning and outcome in patients undergoing surgery for IMSCT.**

INTRODUCTION

Intramedullary spinal cord tumors (IMSCT) account for about 2%—4% of tumors of the central nervous system and about 15% of adult intradural tumors.[1-5] The most common IMSCT include ependymomas and astrocytomas. Unlike most brain tumors, these tumors are often benign and have an insidious onset, with presenting symptoms including paresthesia, weakness, spasticity, gait instability, and bowel/bladder dysfunction. Surgical resection continues to be the most effective treatment modality for most intramedullary tumors, with gross total resection leading to preserved neurologic function and improved survival.[2,6,7] However, surgical treatment is often difficult and carries significant risk of postoperative neurologic complications. Studies have reported deterioration in neurologic function in patients postoperatively,[4,8,9] with rates of dorsal column dysfunction as high as 43.6%—55.1%.[4,10,11] These deficits severely affect the postoperative functionality of patients because they are often left with significant morbidity, worse than their preoperative disease burden.[12-14] Part of the surgical difficulty stems from the inability to identify the appropriate resection plane to delineate the extent of resection. Also, the presence of tumor can distort the normal anatomic architecture of the spinal cord, making it difficult to ascertain the physiologic midline for a myelotomy. As a result of these surgical challenges, intraoperative neuromonitoring (IONM) has gained favorable grounds in facilitating maximal tumor resection and minimizing neurologic morbidity.[15-18]

IONM has been shown to be of clinical importance in the surgical resection of intramedullary spinal cord tumors.[17,19-24] The main monitoring modalities include somatosensory evoked potentials (SSEPs), transcranial motor evoked potentials (TcMEPs) via limb muscles or spinal epidural space (D-waves), and dorsal column mapping (DCM). SSEPs provide information about the functionality of sensory pathways. Despite earlier studies showing reduction of quadriplegia from 3.7% to 0%[25] and from 6.8% to 0.7%[26] using intraoperative SSEP monitoring, postoperative deficits were being reported regardless of the unchanged intraoperative SSEP.[27-30] As a result, TcMEP has been used as a direct method of monitoring motor pathways during surgery for intramedullary spinal tumor and other spinal diseases.[31-33] Consequently, the combined use of SSEP and motor evoked potential (MEP) provides increased accuracy in detecting injury to sensory and motor pathways that can be affected differently depending on the location and morphology of the tumor.[34,35] DCM using microstimulation and SSEP recording is another modality being used to determine anatomic landmarks such as the dorsal median sulcus to guide midline myelotomy. These monitoring modalities have been shown to inform surgeons intraoperatively and in many cases have led to alterations in operative decision. Herein, we reviewed the literature on the usefulness of IONM for intramedullary spinal tumor resection and its role in predicting postoperative neurologic deficits.

METHODS

The MEDLINE database was queried using the following search items: "intramedullary tumor", "spine", "spinal tumor", "monitoring", "neuromonitoring", "somatosensory evoked potential", "motor evoked potential", and "dorsal column mapping". Only articles in English published between 2000 and 2015 were considered. Publications excluded from our search were non-English articles, abstract-only publications, or articles not available via our electronic database queries. Individual case reports were also excluded. Articles were identified and reviewed. Detailed information and data from the selected articles were assessed and compiled.

RESULTS

After an extensive search for available articles, 13 studies were selected for inclusion in this review. Table 1 shows a summary of the relevant clinical studies and the intraoperative monitoring modalities and postoperative changes in neurologic status. One of the articles (study 1) was a historical control study in which patients who underwent surgery for intramedullary spinal tumor with intraoperative monitoring were matched and compared with previously operated patients without monitoring. Two of the articles (studies 5 and 6) were prospective and the remaining 10 studies were retrospective chart reviews. Full review was performed in all 13 articles. These were all clinical studies in which intraoperative neurophysiologic monitoring was used for the surgical resection of intramedullary spinal cord tumors. The number of patients ranged from a minimum of 12 (study 11) to a maximum of 203 (study 5). Among the patients in each study, intraoperative monitoring was successful in 12% of patients in study 2 and 100% of patients in studies 7, 8, and 11–13. MEP, SSEPs, and D-waves were also recorded in most of the studies. One study used DCM (study 2). In general, data collection is by an electrophysiologist under the supervision of a remote neurologist and reported to the primary surgeon responsible for making surgical decisions regarding intraoperative management. The level of experience of the individuals involved is unclear in the studies reviewed.

Two studies reported the sensitivity and specificity in predicting postoperative sensory deficits using SSEP only. In study 7, sensitivity and specificity were 75% and 50%, respectively, for SSEP, whereas in study 12, sensitivity and specificity were 80% and 100%, respectively, for SSEP only. TcMEP was more commonly reported. When the all-or-none criterion was used, the sensitivity/specificity of muscle or myogenic TcMEP only was reported as 95%/98.1% in study 5 and 53%/93% in study 13. When the criterion for a significant TcMEP was defined as greater than 70% deterioration in signal amplitude, the sensitivity increased from 53% (all-or-none criterion) to 79% and the specificity decreased from 93% (all-or-none criterion) to 49% in study 13. In using the combined approach of motor and sensory monitoring, study 7 showed an increase in sensitivity from 100% in MEP only and 75% in SSEP only to 100% in the combined approach. However, in the same study, there was a difference in specificity from 25% in MEP only and 50% in SSEP only to 28.5% in the combined approach. Similarly, in study 13, there was an increase in sensitivity from 80% in SEP and 75% in MEP to 100% in the combined approach, whereas the specificity decreased from 100% in both SEP and MEP to 83.3% when both approaches were combined. Thus, combining SSEP and MEP resulted in increased sensitivity with an overall decrease in specificity.

IONM accurately predicted postoperative outcome in all of the studies included. Sala et al.[17] (study 1) showed the importance of applied MEPs on postoperative neurologic outcomes using a historical control study. The study evaluated 100 patients who underwent surgery for intramedullary spinal tumor and compared the outcomes of patients who had intraoperative monitoring with D-waves or muscle MEP with those without monitoring. These investigators observed a significantly greater improvement in functional outcomes using the McCormick grade 3 months postoperatively in the patients who had intraoperative monitoring (mean, +0.28) compared with the historical cohort without monitoring (mean, −0.54; $P = 0.0016$). Another study (study 6) of 110 patients with spinal tumors (44, intramedullary; 66, extramedullary)[40] showed significantly better motor outcomes in patients with successful intraoperative monitoring during discharge from the hospital. In the same study, postoperative worsening of motor deficits was present in 8% of patients with TcMEP recording compared with 17.1% in patients without monitoring ($P = 0.052$). In addition, Mehta et al.[36] showed a 41% relative decrease in the rate of dorsal column dysfunction. Furthermore, Quinones et al.[37] showed that loss of MEP was associated with worst motor deficits postoperatively. In most of the studies, patients with significant changes in intraoperative monitoring had worse neurologic outcomes postoperatively. Therefore, use of IONM adequately predicted outcomes in patients undergoing surgery for IMSCT.

The extent of resection was also influenced by intraoperative neuromonitoring. Choi et al.[42] (study 9) showed that gross total resection was attainable in 76% of patients with IONM compared with 58% in patients without monitoring ($P = 0.049$). Skinner et al.[20] also indicated that that gross total resection without new postoperative deficits was successful only in patients with no significant change in intraoperative signals. For patients with notable change in signal who still received gross total resection, there were postoperative deficits, including hemiparesis, loss of proprioception, and worsening quadriparesis. This finding implies that the safety of tumor resection can be guided by neuromonitoring.

DISCUSSION

Surgical resection for intramedullary spinal tumors remains a challenging