RESEARCH PAPER

Intraoperative Combined Electrophysiological Monitoring Of Muscle Evoked Potentials And Somatosensory Evoked Potentials In Spinal Tumor Surgery And Its Post Operative Significance

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ABSTRACT

Background: Despite advancement and refinement in neurosurgical operative techniques neurological impairment due to spinal cord surgery remained as high. Various studies incorporated numerous validated techniques for monitoring spinal cord and nerve root functions in spinal tumor (intramedullary, intradural extramedullary, extradural) surgery. Each monitoring techniques (MEP, SSEP, D-wave, EMG) having different sensitivity and specificity. Simultaneously use of Multiple monitoring techniques is advocated to increase the accuracy of IONM. Here we wanted to study the sensitivity and specificity of intraoperative MEP and SSEP in the surgery of spinal lesions and various factors affecting outcome of the surgery.

Aims and Objectives: To determine the Sensitivity, Specificity, Positive predictive value and Negative predictive value of Intraoperative electrophysiological monitoring of MEP and SSEP in spinal tumor surgery and to study the association of various factors in determining the outcome of the surgery.

Material and Methods: It is a prospective and observational study of patients undergoing surgery for spinal tumor at Apollo Specialty Hospital, Chennai. The duration of the study was from June 2016 to August 2020. Patient functional assessment was graded as per Modified McCormick scale. Tumor location, level and extent are determined from patients MRI spine image. A detailed clinical neurological examination is done and Patient's functional assessment was graded as per Modified McCormick scale at the time of discharge. Extent of resection was determined based on follow-up MRI scan.

Inclusion criteria: Patients undergoing Spinal tumor surgery with intraoperative Neuromonitoring of MEP and SSEP.

Exclusion criteria: 1) Patient age less than 10 years, 2) Patients with raised ICP, 3) Patients Undergoing spinal tumor surgery without intraoperative neuromonitoring.

Results: Sensitivity and Specificity of Intraoperative MEP change was 80% and 98% respectively. PPV and NPV of Intraoperative MEP change was 80% and 98% respectively. Sensitivity and Specificity of Intraoperative SSEP change was 80% and 96% respectively. PPV and NPV of Intraoperative SSEP change was 66.7% and 98% respectively. Sensitivity and Specificity of combined Intraoperative MEP and SSEP change was 100% and 94% respectively. PPV and NPV of combined Intraoperative MEP and SSEP change was 62.5% and 100% respectively.

Conclusion: Intraoperative Neuromonitoring is an essential tool in the spinal tumor surgery. IONM helps in identification and preservation of vital structures during surgery and better neurological outcome postoperatively. It gives confidence to the surgeon while operating, knowing the fact that neural structures are neuro-physiologically intact

Keywords: IONM, MEP, SSEP

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INTRODUCTION

Spine tumors are classified historically as (1) extradural, (2) intradural extramedullary, and (3) intradural intramedullary[1]. Extradural tumors are the most common spinal tumors, often being metastatic.[2,3]

Intraspinal tumours include tumour arising from spinal meninges, cauda equina, spinal nerves and spinal cord. Primary intraspinal tumours are rare with rates of 0.9 to 1.29 per 100,000. The most common being cauda equina or the spinal nerves (41%), followed by spinal cord tumour (31%) and tumour arising from spinal meninges (27%). Non-malignant (78.0%) being common than malignant (22%). Malignant tumours being common in age group between

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60-69years. Malignant spinal tumours distributed almost equally in males and females. whereas among non-malignant cases approximately 60% seen in women and 40% in men. The most common tumours are nerve sheath tumour, followed by meningioma and ependymoma, astrocytoma[3,4]. Other spinal intradural cystic lesions are arachnoid cyst, neuroepithelial cyst and endodermal cyst.[5]

Descriptions of first surgical excision of intradural spinal cord lesion dates back to 1888 by Gowers and Horsley. Intramedullary spinal cord tumor was successfully excised for the first time by Eiselsberg in 1907[6] Despite advancement and refinement in neurosurgical operative techniques neurological impairment due to spinal cord surgery remained as high ranging from 3.7 to 7.5%.[7,8]

Intraoperative neuromonitoring (IONM) is used during surgery to identify vital structures during surgery, thus avoiding damage to vital structures and prevent post-operative neurological deficits. There are different modalities of IONM, most commonly used modalities in spine surgery are motor evoked potentials (MEPs), somatosensory evoked potentials (SSEPs).[18]

MEPs can be generated either by Transcranial electrical stimulation (TES) or by transcranial magnetic stimulation (TMS), former being more resistant to anaesthesia is commonly used[19]. These potentials can be recorded directly over either spinal cord (D-waves) or from muscles (Tc-MEP). Tc-MEP is most commonly employed in IONM[18]. Trains of 3–7 electrical impulses, with interpulse interval 1– 5 msec will be applied using corkscrew trans cranial electrodes. MEPs are recorded from needle electrodes placed in muscles.[11]

SSEPs are elicited from peripheral nerves and recorded from scalp electrodes. SSEPs are continuously recorded and compared with the baseline recordings. Since SSEP requires averaging of the potential, there will be slight lag from real time physiological response.[11]

Tamaki and Yamane introduced spinal cord potential measurements and subsequently use of somatosensory-evoked potentials (SSEPs) monitoring reduced morbidity from 6.8% to 0.7%[9,10]. Since SSEP only monitors the integrity of posterior column, many patients with intact SSEP recordings showed post-operative weakness in limbs[11-16]. After introduction of Motor Evoked potential by Merton and Morton in 1980 helped in monitoring of motor component of spinal cord[17]. Forster et al., reported 95% sensitivity and 98.9% specificity in predicting postoperative motor deficits with MEP monitoring.[18]

Various studies incorporated numerous validated techniques for monitoring spinal cord and nerve root functions in spinal tumor (intramedullary, intradural extramedullary, extradural) surgery. Each monitoring techniques (MEP, SSEP, D- wave, EMG) having different sensitivity and specificity. Simultaneously use of Multiple monitoring techniques is advocated to increase the accuracy of IONM[20]. Here we wanted to study the sensitivity and specificity of intraoperative MEP and SSEP in the surgery of spinal lesions and various factors affecting outcome of the surgery.

MATERIAL AND METHODS

Study site: Apollo Specialty Hospital, Chennai.

Study population: Patients admitted to Apollo Specialty Hospital, Chennai.

Study design: Observational prospective study. **Study duration:** From June 2016 to August 2020. **Inclusion Criteria:**

Patient age 10 years and above with no upper limit

Patient admitted to Apollo Speciality Hospital, Chennai

Patient admitted between June 2016 and August 2020

Patients undergoing Spinal tumour surgery with intraoperative Neuromonitoring of MEP and SSEP.

Patients were included in the study only after fulfilling all of the above criteria.

Exclusion Criteria:

Patient age less than 10 years

Patients with raised ICP

Patients with Intracranial electrodes

Patients Undergoing spinal tumour surgery without intraoperative neuromonitoring.

Patients with seizure disorder

METHODOLOGY:

Patients who satisfy the inclusion criteria are admitted and a detailed history is obtained and a detailed clinical neurological examination is done. Patient functional assessment was graded as per Modified McCormick scale. Tumour location, level and extent are determined from patients MRI spine images. Patients were informed about their disease condition and informed consent is obtained for the surgery. Patients are informed about the study in their native language by using patient information sheets and consent is taken from patients willing to participate in the study. A unique identification no. is given to each patient in the study. Intraoperatively MEP and SSEP monitoring done during the surgery. Baseline MEP and SSEP and intraoperative MEP and SSEP changes analysed and co-related to the post-operative neurological condition of the patient. A detailed clinical neurological examination is done and Patient's functional assessment was graded as per Modified McCormick scale at the time of discharge. Extent of resection was determined based on follow-up MRI scan.

OBSERVATION AND RESULTS

Table 1. Distribution of the Participants in Terms of Age (Years) (n = 55).

Age (Years)	
Mean (SD)	44.60 (16.09)

Median (IQR)	46 (32.5-57)
Range	10 – 73

The variable Age (Years) was normally distributed (Shapiro-Wilk Test: $p = 0.206$).
The mean (SD) of Age (Years) was 44.60 (16.09). The median (IQR) of Age (Years) was 46.00 (32.5-57). The Age (Years) ranged from 10 - 73.

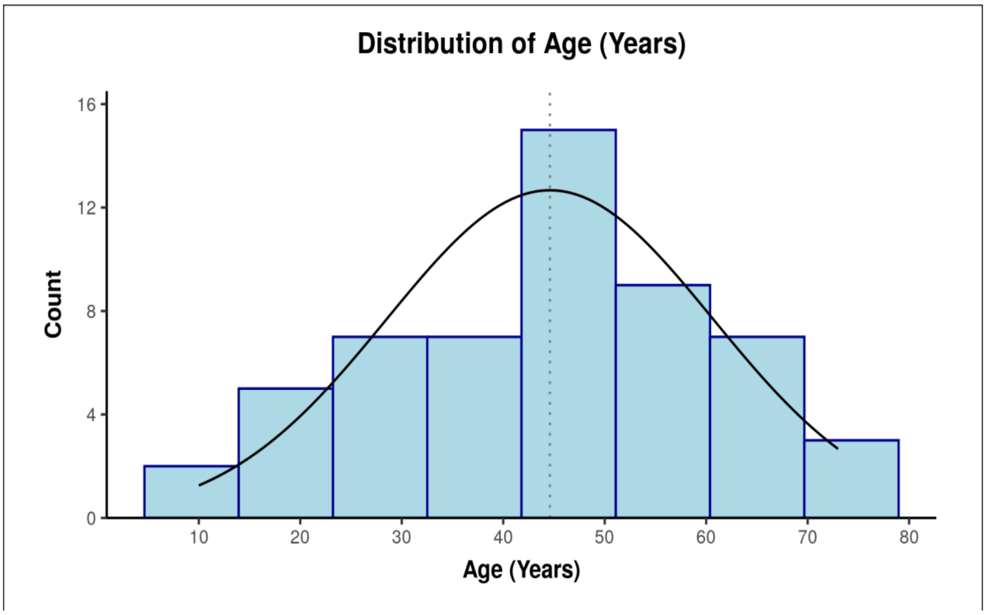

Figure 1. Distribution of Age.

Table 2. Distribution of the Participants in Terms of Age (n = 55).

Age	Frequency	Percentage
≤20 Years	7	12.7%
21-30 Years	3	5.5%
31-40 Years	11	20.0%
41-50 Years	14	25.5%
51-60 Years	10	18.2%
61-70 Years	8	14.5%
71-80 Years	2	3.6%
Total	55	100.0%

12.7% of the participants had Age: ≤20 Years. 5.5% of the participants had Age: 21-30 Years. 20.0% of the participants had Age: 31-40 Years. 25.5% of the participants had Age: 41-50 Years. 18.2% of the participants had Age: 51-60 Years. 14.5% of the participants had Age: 61-70 Years. 3.6% of the participants had Age: 71-80 Years.

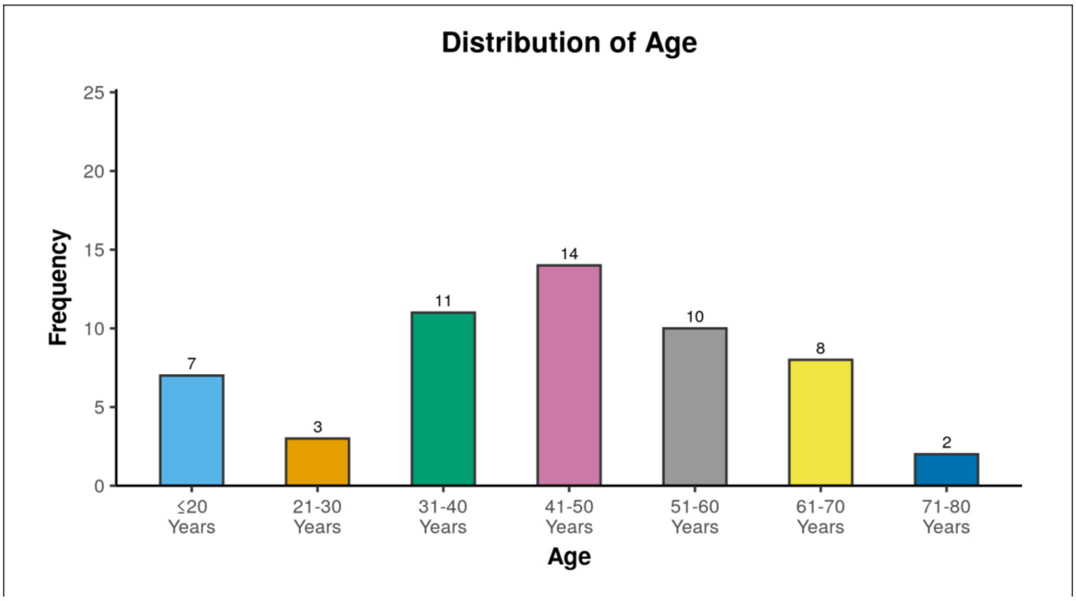

Figure 2. Frequency of distribution of age.

Table 3. Distribution of the Participants in Terms of Gender (n = 55).

Gender	Frequency	Percentage
Male	33	60.0%
Female	22	40.0%
Total	55	100.0%

60.0% of the participants had Gender: Male. 40.0% of the participants had Gender: Female.

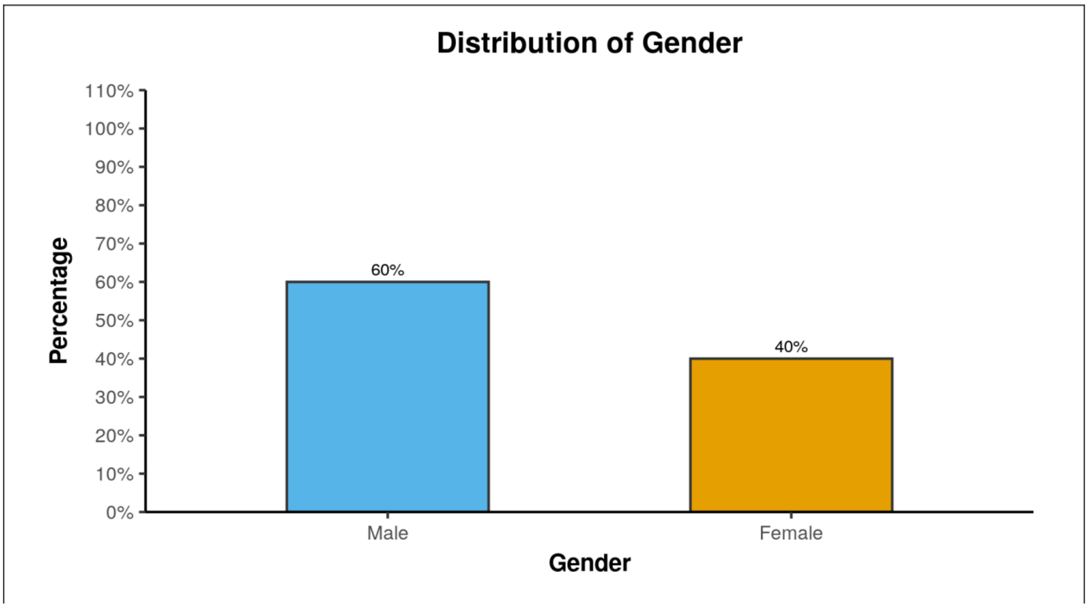

Figure 3. Distribution of Gender.

Table 4. Distribution of the Participants in Terms of Co-Morbidity: Any (n = 55).

Co-Morbidity: Any	Frequency	Percentage
Present	26	47.3%
Absent	29	52.7%
Total	55	100.0%

47.3% of the participants had Co-Morbidity: Any: Present. 52.7% of the participants had Co-Morbidity: Any: Absent.

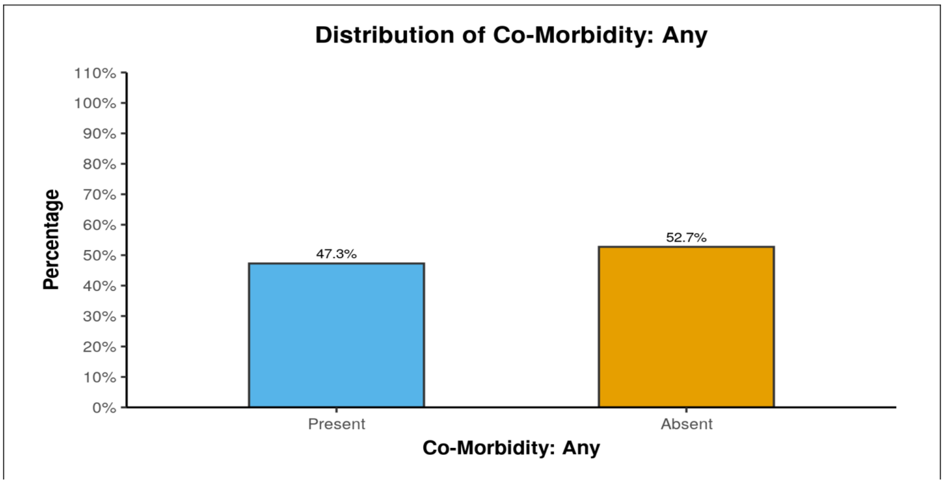

Figure 4. Distribution of Co-Morbidities.

Table 5. Summary of Co-Morbidity.

Co-Morbidity	Present	Absent
Any	26 (47.3%)	29 (52.7%)
Diabetes	11 (20.0%)	44 (80.0%)
Systemic Hypertension	16 (29.1%)	39 (70.9%)
CAD	5 (9.1%)	50 (90.9%)
Hypothyroidism	3 (5.5%)	52 (94.5%)
Metastatic Carcinoma	3 (5.5%)	52 (94.5%)

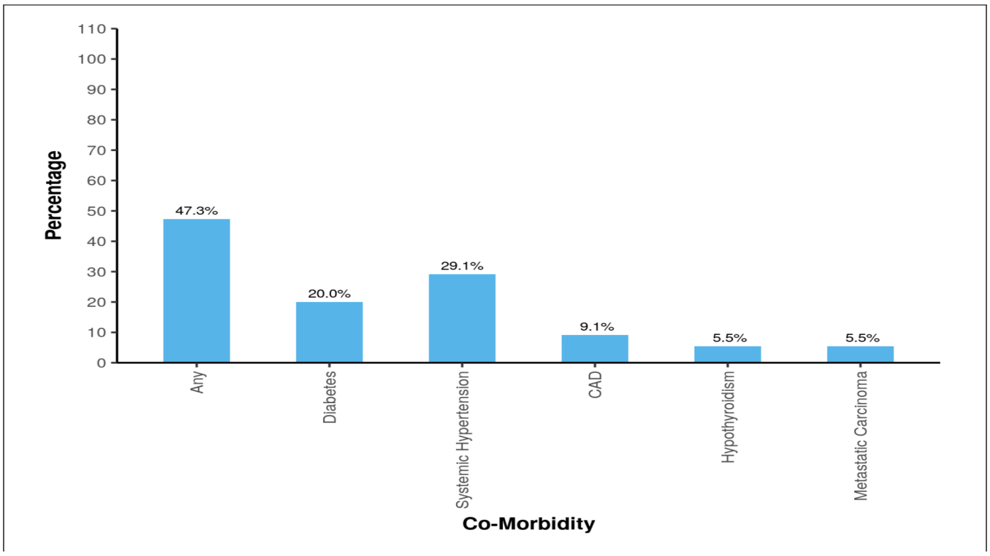

Figure 5. Summary of Co-Morbidities.

26 (47.3%) of the participants had Co-Morbidity: Any: Present. 29 (52.7%) of the participants had Co-Morbidity: Any: Absent.
11 (20.0%) of the participants had Co-Morbidity: Diabetes: Present. 44 (80.0%) of the participants had Co-Morbidity: Diabetes: Absent.
16 (29.1%) of the participants had Co-Morbidity: Systemic Hypertension: Present. 39 (70.9%) of the participants had Co-Morbidity: Systemic Hypertension: Absent.
5 (9.1%) of the participants had Co-Morbidity: CAD: Present. 50 (90.9%) of the participants had Co-Morbidity: CAD: Absent.
3 (5.5%) of the participants had Co-Morbidity: Hypothyroidism: Present. 52 (94.5%) of the participants had Co-Morbidity: Hypothyroidism: Absent.
3 (5.5%) of the participants had Co-Morbidity: Metastatic Carcinoma: Present. 52

(94.5%) of the participants had Co-Morbidity: Metastatic Carcinoma: Absent.

Table 6. Distribution of the Participants in Terms of Initial Symptoms (n = 55).

Initial Symptoms	Frequency	Percentage
Back Pain	26	47.3%
Difficulty In Walking	7	12.7%
Dysesthesia	7	12.7%
Weakness In Lower Limb	5	9.1%
Neck Pain	3	5.5%
Pain In Upper Limb	2	3.6%
Sensory Loss	2	3.6%
Weakness In Upper And Lower Limb	2	3.6%
Weakness In Upper Limb	1	1.8%
Total	55	100.0%

47.3% of the participants had Initial Symptoms: Back Pain. 12.7% of the participants had Initial Symptoms: Difficulty In Walking. 12.7% of the participants had Initial Symptoms: Dysesthesia. 9.1% of the participants had Initial Symptoms: Weakness In Lower Limb. 5.5% of the participants had Initial Symptoms: Neck Pain. 3.6% of the participants had Initial Symptoms: Pain In Upper Limb. 3.6% of the participants had Initial Symptoms: Sensory Loss. 3.6% of the participants had Initial Symptoms: Weakness In Upper And Lower Limb. 1.8% of the participants had Initial Symptoms: Weakness In Upper Limb.

DISCUSSION

Out of 55 patients included in our study, patients who underwent spinal tumor surgery using IONM, 5 (9.1%) had new neurological deficits after surgery. On an average in spinal tumors (intramedullary, intradural extramedullary, extradural) it ranged from as high as 22% to as low as 7.6%. Which was 22% in Sutter et al.,[19] 2007, 20% in Krammer et al.,[20] 2009, 11.3% in Forster et al.,[17] 2012, 16.5% in Chang et al., [21] 2016, 7.6% in Velayutham et al.,[22] 2016.

In spite of using intraoperative neuromonitoring post-operative neurological deficits after surgery were higher in intramedullary spinal cord tumors. It was 38% in Kothbauer et al.,[23] 1998, 57.14% Skinner et al.,[24] 2004, 23.52% Hyun et al.

2019, 34% Garcés-Ambrossi et al.,[25] 2009. 31.5% Matsuyama et al.,[27]. In only spinal ependymomas series by Li et al., it was lower compared to other series with intramedullary spinal tumor excision, it ranged from 10% to 17% depending on the length of the tumor[23,24]. This may be due to clear plane of resection in ependymomas compared to spinal astrocytoma[26]. In our study we had 9 cases of spinal ependymoma, out of which, only 1 case was noted to have postoperative neurological deterioration which was a case of Cervico-Dorsal involving 8 spinal levels. 5 remained unchanged from pre-operative status. In 3 patients there was an improvement as compared to the preoperative status. However, only one patient showed improvement according to the modified McCormick scale.

In a heterogenous group, studied by Calancie and Molano in 2008, with a large sample size of 903 cases, comprising of spinal tumor (239); tethered cord (125); orthopaedic (512); vascular (22); and cyst (5), the postoperative neurological deficit was noted to be 10.82%.[20]

Post-operative neurological deficits were seen in 23%, even with IONM, in intradural extramedullary tumors excision in the study by korn et al., 2014. New neurological deficits after surgery in extradural spinal tumor excision was only 1% in a case series of 208 patients by Avil et al., 2013, which was much lesser compared to the other groups, probably because extradural tumours do not require spinal dural opening and hence lesser handling of neural structures.

Decreasing amplitudes of 50% or more from the baseline, increasing stimulus intensities of 20% or more from the baseline or increased latencies of more than 10% from the baseline were regarded as significant intraoperative changes in MEP in our study, which is similar to Krammer et al.,[28]. Other warning criteria were used by different authors like the presence/ absence of response was used by Kothbauer et al., 1998, Sala et al., 2006 and Forster et al., 2012. Whereas Krammer et al., 2009, Hyun et al., 2009, Ghadirpour et al., 2015, Chang et al., and Graces-Ambrossi et al., used 50% reduction in amplitude in baseline MEP[28,29]. Choi et al., used an amplitude decrease of 75% or more as a significant change, which is in between complete loss and 50% reduction in amplitude, as the latter will be too sensitive and hence interfere in tumour resection. Calancie & Molano, 2008 has used a different method of threshold increase of >100V. With various methods sensitivity and specificity has varied in these studies.

CONCLUSION:

Intraoperative Neuromonitoring is an essential tool in the spinal tumor surgery. IONM helps in identification and preservation of vital structures during surgery and better neurological outcome postoperatively. It gives confidence to the surgeon while operating, knowing the fact that neural structures are neuro-physiologically intact. But sometimes it may give a false alarm resulting in stopping the surgery prematurely. However Different modalities of IONM like MEP, SSEP, D- wave monitoring, EMG etc., has its own advantages and limitations. Short comings of individual modalities can be overcome by combining multiple modalities to improves the accuracy of the IONM

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