Intradural extramedullary tumor location in the axial view affects the alert timing of intraoperative neurophysiologic monitoring

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Short title: IDEM tumor location and alert timing

Abstract

Objective: Intraoperative neurophysiologic monitoring (IONM) reportedly helps prevent postoperative neurological complications following high-risk spinal cord surgeries. There are negative and positive reports about using IONM for intradural extramedullary (IDEM) tumors. We investigated factors affecting alerts of IONM in IDEM tumor surgery.

Methods: We analyzed 39 patients with IDEM tumors who underwent surgery using IONM at our hospital between January 2014 and March 2021. Neurological symptoms were evaluated pre- and postoperatively using the manual muscle test (MMT). All patients were evaluated to ascertain the tumor level and location in the axial view, the operative time, intraoperative bleeding volume, and histological type. Additionally, the intraoperative procedure associated with significant IONM changes in transcranial electrical stimulation muscle-evoked potential was investigated.

Results: There were 11 false-positive and 16 true-negative cases. There was one true-positive case and one false-negative case; the monitoring accuracy achieved a sensitivity of 50%, a specificity of 59%, a positive predictive value of 8%, and a negative predictive value of 94%. In the 22 alert cases, if the tumor was located anterolateral in the axial view, alerts were triggered with a significant difference (p=0.02) during tumor resection. Alerts were generated for fifteen patients during tumor resection; nine (60%) showed waveform improvement by intervention and were classified as rescue cases.

Conclusions: Alert is probably triggered during tumor resection for anterolaterally located tumors. Alerts during tumor resection procedures were more likely to be rescued than other procedures in IDEM tumor surgery.

Keywords: Intraoperative spinal cord monitoring, Spinal surgery, Intradural extramedullary spinal tumor

Introduction

Nash et al. first reported neurophysiological monitoring in 1977 [1]. Subsequently, intraoperative neurophysiologic monitoring (IONM) has been reported to contribute to the prevention of postoperative neurological complications in high-risk spinal cord surgeries for conditions such as spinal deformity, intramedullary spinal cord tumors (IMSCT), and ossification of the posterior longitudinal ligament (OPLL) [2-5]. For high-risk surgeries, such as corrective surgery for spinal deformity, IMSCT removal, and OPLL decompression that can cause neurological damage, there is abundant information suggesting that IONM can prevent the development of postoperative neurological deficits [6-10].

In contrast, for intradural extramedullary (IDEM) tumors requiring low-risk spinal cord surgery, there are both negative and positive reports on using IONM. Hawksworth et al. [11] reported that the rate of development of new neurological deficits was similar between monitored and non-monitored cases. Conversely, Safaee et al. [9] reported that IONM contributed to gross total tumor resection, and Ishida et al. [12] reported that IONM predicted new postoperative neurological deficits at 6-month follow-up and mitigated neurological injury [13, 14]. Therefore, further research on IONM in patients with IDEM tumors is expected to help prevent postoperative complications.

Furthermore, Fujiwara et al. [15] indicated that there are many false-positive (FP) cases of IONM in IDEM tumors, and Shigematsu et al. [16] reported that non-surgical factors increased FP cases in IDEM tumors. Ushirozako et al. [17] investigated the alert timing and rescue rate of surgery using IDEM tumors in a multicenter study conducted by the Spinal Cord Monitoring Working Group of the Japanese Society for Spine Surgery and Related Research (JSSR). However, IDEM tumors were reported in only a few cases. Therefore, we believe that the timing of true nerve injury can be determined by investigating the alert timing in IDEMs and, consequently, a decrease in FP can be expected.

This study aimed to clarify the condition of neurological damage in the surgery of IDEM tumors by investigating the relationship between the patient background and surgical procedures.

Methods

As shown in Figure 1, based on the inclusion criteria, from January 2014 to March 2021, 100 patients underwent surgery at our institution for intravertebral canal tumors combined with IONM. Of these, patients with IMSCT, epidural tumors, cauda equina tumors, meningeal aneurysms, and dumbbell tumors of Eden classification

Types III or IV that did not compress the spinal cord were excluded. In contrast, patients with dumbbell tumors of Eden classification Types I and II, wherein tumors were in the spinal canal and caused spinal cord compression, were included. The histological type included only frequent schwannoma and meningioma; consequently, 39 patients were included. Neurological symptoms were evaluated using the manual muscle test (MMT), and a preoperative MMT score of 5 was defined as a non-neurological deficit. A reduction in the preoperative MMT scores by ≥1 in more than one muscle (MMT score <5) was defined as a motor deficit. The tumor location in the axial view was divided into two parts based on the occupancy site of the tumor in the spinal canal, namely anterolateral and posterior (Figure 2). We categorized the surgical procedures as those requiring tumor resection or others, which included laminectomy, dura mater incision, and opening or closing of a surgical incision. The tumor location in the axial view was evaluated based on the examiner's match rate. The intra-examiner concordance rate for tumor location in the axial view was 97.4% (38/39).

General anesthesia was induced by total intravenous anesthesia using propofol in all cases. At the time of intubation, a muscle relaxant (rocuronium) was intravenously administered. After orienting the patient in the prone position, a muscle relaxant antagonist (sugammadex sodium), which was administered before monitoring, was initiated. Moreover, body temperature, blood pressure (BP), pulse, oxygen saturation, and bispectral index were continuously monitored during the surgery. All patients underwent posterior open approaches, either laminectomy or laminoplasty, for tumor resection.

IONM was performed using a 14-channel transcranial electrical stimulation muscle evoked potential (TES-MEP) and somatosensory evoked potential (SEP) using a Neuro-master MEE-1200 system (Nihon Kohden). Transcranial electrical stimulation spinal cord-evoked potential (TES-SCEP) was performed in patients at a high risk of postoperative paralysis, as determined by the surgeon. The TES-MEP stimulation electrodes were placed 2 cm anterior and 5 cm lateral to the Cz (international 10–20 system of electrode placement) over the cerebral cortex motor area, with parameters of five stimulations in a row at 2-ms intervals, a constant biphasic current of 120–200 mA for 1 min. Recordings were made using electrodes placed bilaterally from the deltoid, biceps brachii, and abductor digital minimum in the upper extremities and bilaterally from the quadriceps, tibialis anterior, gastrocnemius, and abductor hallucis in the lower extremities. The TES-SCEP USY-100-2PMC (Unique Medical Corporation) was inserted into the epidural space as a lead-out electrode. We set a 70% amplitude reduction as the alarm point of TES-MEP, based on the recommendations of the Spinal Cord Monitoring Working Group of the

JSSR [18]. We defined the prolongation of latencies of more than 10% from the baseline SEP as a significant change. Moreover, a decrease of more than 50% of the baseline amplitude of TES-SCEP was considered a warning criterion for permanent motor deficits. TES-MEP and SEP were used in all cases, and TES-SCEP was used in 19 cases. Upon observing any significant TES-MEP changes, the inspector sent an alert, and the anesthesia state as well as general condition (BP and body temperature) were checked. In the case of no problems, the surgeons decided between temporary surgical cessation, surgical field irrigation, and withdrawal from the surgery, based on the nature of the cases, as an intervention. No steroids were administered. If the TES-MEP waveform amplitude reduction improved to less than 70%, we judged it as waveform recovery and continued the surgery. If waveform recovery was not observed, we continued the surgery till the SEP and TES-SCEP did not change.

We defined a reduction in the MMT score by ≥1 after surgery as a postoperative neurological deficit. A true-positive (TP) TES-MEP alert was defined as an alert followed by the observation of a new postoperative neurological deficit. An FP TES-MEP alert was defined as an alert that persisted despite a new neurological deficit. A true-negative (TN) was defined as the absence of any TES-MEP alert during surgery with no new postoperative deficit. A false-negative (FN) was defined as the absence of an alert in a patient with a new postoperative motor deficit. Cases with alerts, waveform improvement during surgery after the intervention, and no postoperative motor deficit were defined as “rescue cases.” Based on the report by Ushirozako et al. [17], during statistical analysis, rescue cases were excluded from the accuracy because we were not convinced about the temporal decrease in amplitude real postoperative neurological deficit without a wake-up test.

Data are presented as mean ± standard deviation unless otherwise specified. At first, we compared the alert group and the non-alert group. The tumor resection and non-tumor resection groups were compared in a sub-analysis to determine the true alert. Intergroup comparisons of categorical variables were performed using Fisher’s exact test, while continuous variables were examined using the Wilcoxon test. All analyses were performed using JMP Pro version 15.1 (SAS Institute Inc., Cary, NC, USA), with statistical significance set at $p<0.05$.

This study was approved by the Institutional Review Board of Kurume University (Approval Number: 15198) and written informed consent was obtained from all the participants.

Results

Table 1 summarizes the demographics and surgical status of 39 patients who fulfilled the inclusion criteria and were classified into the alert and non-alert groups. A significant change in IONM with a 70% amplitude reduction in TES-MEP was detected in 22 cases, while no significant change in IONM was detected in all procedures in 17 cases. The average population age was 61 (range: 32–84) years in the alert group and 66 (range: 38–81) years in the non-alert group. There were 17 cases (77%) in the alert group and 9 cases (53%) in the non-alert group, wherein the tumor location in the axial view was anterolateral. A comparison between the group with alerts (22 cases) and those without alerts (17 cases) revealed no significant differences in terms of any of the factors between the two groups.

The 39 cases included 1 TP case, 11 FP cases, 1 FN case, 16 TN cases, and 10 Rescue cases, yielding a sensitivity of 50%, specificity of 59%, positive predictive value (PPV) of 8%, and negative predictive value (NPV) of 94% (Table 2).

In this study, we encountered two cases of paralysis (one FN case and one TP case). The FN case was of a 71-year-old woman with C4/5 level Eden classification I dumbbell tumor, schwannoma of the left side. Motor paralysis of the left deltoid muscle (MMT 3) was observed preoperatively. MMT decreased in the muscle immediately after surgery, while the sensory supply of the proximal left upper arm showed dysfunction. Two years postoperatively, the paralysis was transient as the left deltoid muscle recovered to MMT 4 with improvement in sensory disorders. The left unilateral arch resection, C4/5 intervertebral hole enlargement, and C5 root sacrifice were performed using a microscope. The tumor was grossly removed when viewable from a microscope, and no waveform reduction of monitoring was observed during the surgery. The TP case was of a 64-year-old man with a tumor at the C4/5 level on the right side, which added pressure on the spinal cord laterally. Preoperatively, only a decrease in sensory supply to the right proximal upper arm was observed; however, immediately after the surgery, a decrease was observed in the right deltoid muscle and biceps of more than MMT 1; similarly, we observed a decrease in sensory supply on the left side at the C5 level. The right upper arm motor deficit improved four months after the surgery, and only the original sensory disorder remained. In the surgery, right-sided hemi-laminoplasty was performed using a microscope, the inner and outer layers of the dura mater were detached, and the tumor was excised intraocularly with the inner layer. During tumor excision, the TES-MEP waveform of the right deltoid muscle, biceps, and both lower limbs decreased by more than 70%. Despite the cessation and intervention with irrigation, there was no recognizable improvement in waveform.

Details, such as the tissue type, location, surgical procedure at alert, intervention, waveform change at the end of the surgery, postoperative neurological deficit, and correlation of the 22 cases in the alert group, are shown in Table 3. There were seven cases (32%) in the non-resection tumor group and 15 (68%) in the tumor resection group. In the intervention group, cessation was performed in all cases. BP elevation and irrigation were performed if waveform recovery was not achieved by cessation. In Case 16, the waveform improved after removing blood-saturated sponges covering the dura. In one TP case (Case 12), waveform deterioration was observed during tumor resection, and intervention was performed; however, the waveform did not recover. Only one (Case 13) of the seven cases of non-tumor resection was a rescue case, wherein the alert was triggered by laminectomy, and the waveform recovery was observed by intervention. Nine (Cases 14–22) of the 15 tumor resection cases achieved waveform recovery and were, therefore, identified as rescue cases. All 11 FP cases underwent SEP; however, waveform could not be derived for 6 (55%) patients at the start of surgery. TES-SCEP was performed on 6 patients, and one patient (17%) could not derive waveform at the start of surgery. Consequently, either SEP or SCEP could be derived in 7 (Cases 1, 3, 4, 5, 6, 9, and 10) of the 11 FP cases. Although TES-MEP showed significant waveform deterioration, SEP and TES-SCEP did not show any significant waveform deterioration; therefore, the operator completely removed the tumor without hesitation.

We compared 15 and 7 cases in the tumor and non-tumor resection groups, respectively, based on the patient characteristics (Table 4). The tumor location in the axial view in the tumor resection and non-resection tumor groups was as follows: anterolateral, 14 (93%) vs. 3 (43%); posterior, 1 (7%) vs. 4 (57%), respectively. A significant difference was observed between the two groups in terms of tumor location in the axial view ($p=0.02$). Similarly, there was a significant difference in the operation time ($p=0.03$) between the tumor resection group (236±53 min) and the non-resection tumor group (263±82 min). Of the 15 cases wherein alerts were sent during tumor resection, nine (60%) showed waveform improvement due to intervention. In contrast, of the seven cases wherein alerts were sent during times other than during tumor resection, one (14%) showed waveform improvement due to intervention.

Discussion

In this study, we observed that waveform changes during tumor resection procedures were likely to occur in cases wherein the tumor was anterolateral (p=0.02). In addition, although there was no significant difference, the number of rescued cases tended to be greater in the tumor resection group (60%) than in the non-tumor resection group (14%). Although previous reports [15] have shown that an anterolateral location of the tumor is a risk factor for waveform change during operation, no studies have simultaneously examined the relationship between tumor location and surgical procedure. Thus, to the best of our knowledge, this is the first study to demonstrate the relationship between alert timing and tumor location in the axial view in the surgery of IDEM tumors.

This study included two cases of postoperative neurological deficit (one FN case and one TP case). The FN case was of transient C5 paralysis. A previous report stated that the segmental spinal cord injury or selective damage of the nerve root does not necessarily affect the waveform change in TES-MEP [19]. The TP case was of a meningioma, which required detachment of the inner and outer layers of the dura mater, resulting in a wide range of TES-MEP waveform changes and postoperative deficit of the right deltoid muscle. In this case, since there was no permanent paralysis or recurrence of the tumor one year postoperatively, the TES-MEP alert criterion of 70% amplitude reduction as the alarm point seems appropriate for IONM in IDEM tumors. Several reports have recommended the multimodality of IONM in the surgery of IDEM tumors [12, 14, 20, 21]. In this case, using the SEP combination treatment and the absence of a decrease in SEP waveform during surgery seemed to have facilitated the complete removal of the tumor using a microscope.

For the 11 FP cases in our study, either SEP or SCEP could be derived in 7. In contrast, there were four cases in which neither SEP nor TSE-SCEP could be derived. Two of the four cases in which SEP and SCEP waveforms could not be derived, these waveform changes in TES-MEP occurred during deployment or closure and thus did not affect the complete resection of the tumor. Shigematsu, et al. [16] reported that waveform decline during non-surgical procedures such as deployment and wound closure tends to cause FP. In one patient, TES-MEP was used to monitor eight muscles of both lower extremities. Only one muscle of the left abductor hallucis showed a significant change in waveform during tumor resection, so the tumor was completely removed at the operator's discretion. The other patient was an 80-year-old woman with a history of cerebral infarction who originally had MMT 4 paralysis of the right lower extremity. During the procedure of tumor resection, she had a significant waveform change in both lower extremities. Although intervention improved the waveform in most muscles, no recovery of the waveform in the right abductor hallucis was observed. The operator decided that the tumor was capsular and complete removal could be achieved, and the operation was continued with no waveform improvement at the surgeon's discretion. However, Funaba et al. [22] stated that when intraoperative waveform decline occurs in a patient with preoperative paralysis, there is a high possibility of postoperative paralysis exacerbation. Thus, it was necessary to abort the surgery when the waveform decline was noticed in this case with cerebral infarction.

Several reports comparing the alert and non-alert groups have indicated that preoperative paralysis affects alert transmission [23-25]. However, no such difference was observed in our study. In this regard, as the number of cases increased, the same tendency that the presence of preoperative paralysis affects alert transmission, as reported in previous studies, may be observed. Although we evaluated neurological deficits using the MMT, the method of evaluating neurological symptoms differs between studies.

Regarding the procedure that triggered alerts in surgery of IDEM tumor, Yoshida et al. [26] reported that trigger rates for tumor resection and root sacrifice combined were 62.7%, while for other reasons, they were 30.5%; these results are similar to our study findings, including 15 cases (68%) of tumor resection and seven cases (32%) of non-resection tumors. There was a significant difference in tumor location in the axial view (p=0.02) between the tumor resection and non-resection tumor groups. These results are consistent with those of Ghadirpour et al. [20], who reported that the anterolateral location of the tumor is an independent risk factor for changes in IONM. IONM is a surgical support tool that helps surgeons decide whether to proceed with the operation or perform an intraoperative intervention. However, a disadvantage of IONM is that the criteria for waveform reduction vary across facilities, and the methods of interventions differ among surgeons. In this study, 60% of patients in the tumor resection group were rescued, compared to only 14% in the non-resection tumor group. This result indicates that it is desirable to actively perform intraoperative intervention when waveform reduction, as the alarm point, occurs during the tumor resection procedure. This important information is expected to help surgeons determine whether to continue the surgery.

The non-resection tumor group tended to have longer operation times than the tumor resection group (tumor resection group vs. non-resection tumor group: 236±53 vs. 263±82, p=0.03). Furthermore, although there was no significant difference, intraoperative blood loss was greater in the non-resection tumor group than in the tumor resection group (tumor resection group vs. non-resection tumor group: 95±59 mL vs. 152±113 mL). The phenomenon that waveform-change is likely to occur when operation time is longer is known as "Anesthetic fade [24, 25]". We believe that the study outcomes could be attributed to this phenomenon. Of the seven cases in the non-resection tumor group, only one rescue case showed a waveform change with a decrease in BP during laminectomy. The BP started increasing with the use of a vasopressor in addition to intraoperative interventions such as cessation and irrigation, resulting in the recovery of the waveform. Herein, the waveform change may be caused by factors related to general conditions such as hypotension, body temperature, and anesthesia. This information can help avoid unnecessary extension of the operation time and intraoperative spinal cord damage by rapidly identifying the cause other than the factors related to the procedure and performing requisite intervention accurately.

This study has some limitations, such as its retrospective single-center design and the small number of cases, which reduced the power of statistical analysis. In our study, IONM was performed using TES-MEP and SEP. However, monitoring accuracy was determined considering only the TES-MEP result because TES-SCEP was used in only 19 cases. We considered that the relationship between TES-MEP and alert timing could not be accurately examined if we included the SEP and TES-SCEP results when evaluating the correlation. Hence, further studies are required to determine the accuracy of multimodal examination methods such as TES-MEP, TES-SCEP, and SEP [27, 28]. Additionally, although the alert timing was compared between the tumor resection group and the non-resection tumor group, it is desirable to investigate the relationship between the waveform and more detailed procedures since the procedures differ in different tumor tissue types.

Conclusion

Our results suggest that an alert is likely to be triggered during tumor resection if the tumor is anterolaterally located. In addition, cases generating alerts during tumor resection procedures were more likely to be rescued than other procedures. To the best of our knowledge, this is the first study demonstrating that tumor location in the axial view affects alert timing in IDEM surgery. Nevertheless, a prospective evaluation of this association while using multimodality is warranted.

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Figure legends

Fig. 1 Study design

IONM, Intraoperative neuromonitoring; IMSCT, Intramedullary spinal cord tumor; EDSCT, Extradural spinal cord tumor; CET, Cauda equina tumor; IDEM, Intradural extramedullary tumors

Fig. 2 Tumor location in the axial view (A) Location of the tumor in the axial view is classified into three parts based on the main occupancy site of the tumor in the spinal canal: anterior (ventral site), lateral, and posterior (dorsal site). Furthermore, the anterolateral and posterior areas are displayed in yellow and red, respectively. (B) Anterolateral (schwannoma), (C) anterolateral (meningioma), and (D) posterior (meningioma) locations

Table 1. Comparison of baseline and surgical factors between the alert and non-alert groups

Variable	No. of patients (N=39)		p-value
	Alert group (n=22)	Non-alert group (n=17)	
Age, years	61±14	66±12	0.24
Sex			0.10
Male	12	4	
Female	10	13	
Preoperative neurological deficit			0.52
No deficit (MMT score of 5)	13	12	
Deficit (MMT score <5)	9	5	
Tumor level			1.00
Cervical	5	3	
Thoracic	17	14	
Tumor location			0.17
Anterolateral	17	9	
Posterior	5	8	
Duration of surgery, min	245±72	217±98	0.30
Estimated blood loss, mL	112±81	153±126	0.21
Pathology			1.00
Schwannoma	14	11	
Meningioma	8	6	
Postoperative neurological deficit	1	1	0.82

Values are expressed as the number of patients (%) or mean ± standard deviation.

MMT, manual muscle test.

Table 2. Crosstables of true positive, false positives, false negative, true positives

TES-MEP results	Postoperative neurological change	
	Neurological deficit	Non-neurological deficit
Significant change in IONM	True positive 1	False positive 11
No significant change in IONM	False negative 1	True negative 16

Values are expressed as the number of patients of each outcome.

TES-MEP, transcranial electrical stimulation muscle evoked potential.

IONM, intraoperative neurophysiologic monitoring.

Table 3. Procedures and interventions in the alert group

Case no.	Age/sex	Tissue	Location	Procedure	Intervention	Waveform at the end of surgery	Postoperative neurological deficit	Correlation
1	68 / F	M	Posterior	Laminectomy	Cessation	No recovery	No	FP
2	32 / F	S	Posterior	Laminectomy	Cessation + BP elevation	No recovery	No	FP
3	67 / F	M	Posterior	Laminectomy	Cessation + BP elevation	No recovery	No	FP
4	52 / M	S	Anterolateral	Dural incision	Cessation	No recovery	No	FP
5	51 / F	S	Posterior	Laminectomy	Cessation + BP elevation	No recovery	No	FP
6	39 / M	S	Anterolateral	Laminectomy	Cessation + BP elevation	No recovery	No	FP
7	61 / F	M	Anterolateral	Resection	Cessation+ irrigation	No recovery	No	FP
8	62 / M	S	Anterolateral	Resection	Cessation	No recovery	No	FP
9	33 / F	M	Anterolateral	Resection	Cessation + BP elevation	No recovery	No	FP
10	80 / F	S	Anterolateral	Resection	Cessation + BP elevation	No recovery	No	FP
11	39 / M	S	Anterolateral	Resection	Cessation elevation	No recovery	No	FP
12	64 / M	M	Anterolateral	Resection	Cessation	No recovery	Yes	TP
13	57 / M	S	Anterolateral	Laminectomy	Cessation + BP elevation	Recovery	No	Rescue
14	79 / M	S	Posterior	Resection	Cessation+ irrigation	Recovery	No	Rescue
15	52 / F	S	Anterolateral	Resection	Cessation	Recovery	No	Rescue
16	57 / M	S	Anterolateral	Resection	Cessation blood-saturated sponges	Recovery	No	Rescue

17	84 / F	M	Anterolateral	Resection	Cessation + irrigation	Recovery	No	Rescue
18	64 / F	M	Anterolateral	Resection	Cessation + irrigation	Recovery	No	Rescue
19	69 / M	S	Anterolateral	Resection	Cessation + irrigation	Recovery	No	Rescue
20	67 / M	M	Anterolateral	Resection	Cessation	Recovery	No	Rescue
21	76 / M	S	Anterolateral	Resection	Cessation + BP elevation	Recovery	No	Rescue
22	66 / M	S	Anterolateral	Resection	Cessation + irrigation	Recovery	No	Rescue

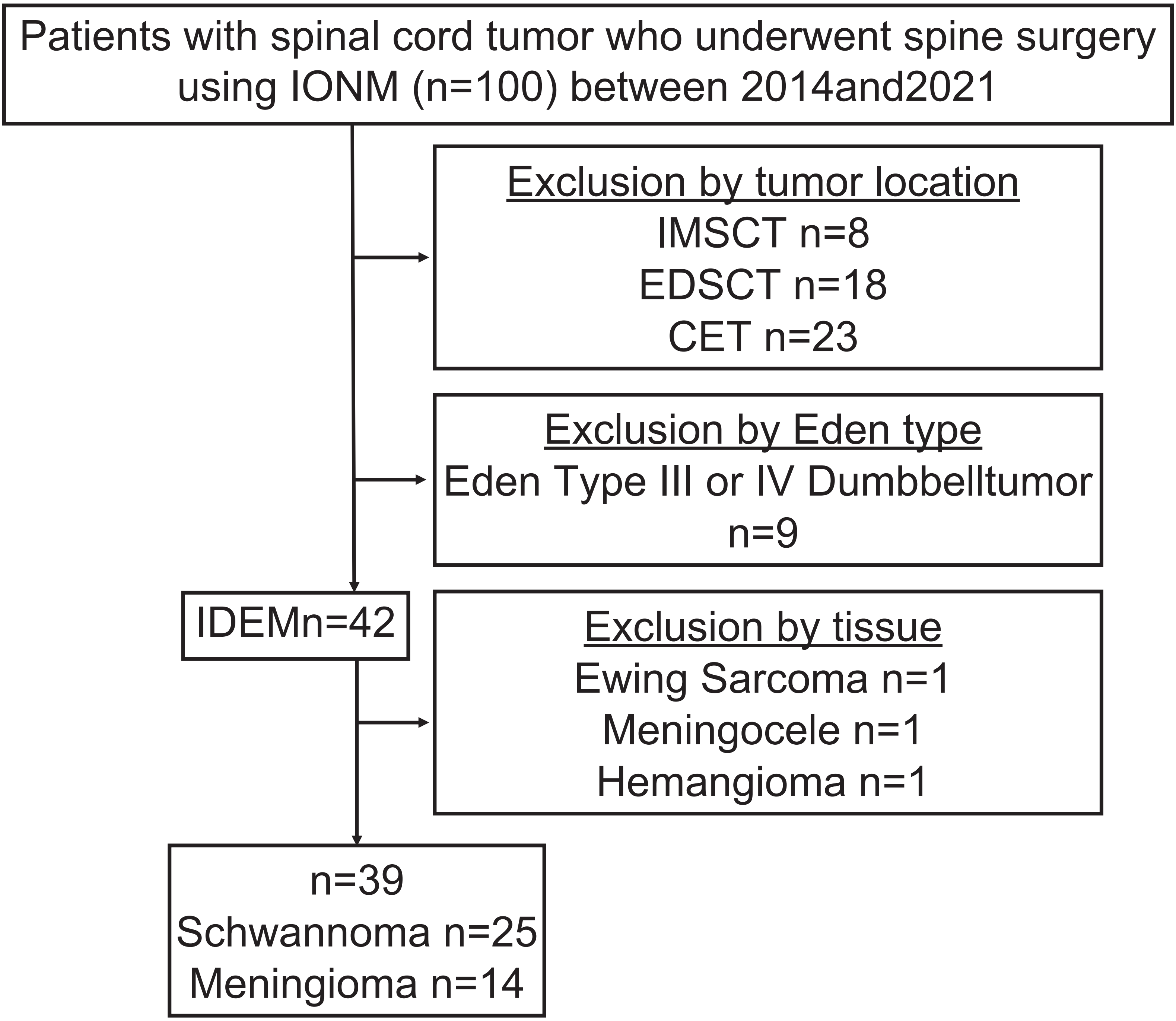
M, Male; F, Female; S, Schwannoma; M, Meningioma; BP, blood pressure; FP, false positive; TP, true positive

Table 4. Comparison of different procedures in the tumor and non-tumor resection groups

Variable	Alert group (n=22)		p-value
	Tumor resection (n=15)	Non-tumor resection (n=7)	
Preoperative neurological deficit			0.65
MMT score of 5	8	5	
MMT score <5	7	2	
Tumor level			1.00
Cervical	3	2	
Thoracic	12	5	
Tumor location			**0.02***
Anterolateral	14	3	
Posterior	1	4	
Duration of surgery, min	236±53	263±82	**0.03***
Estimated blood loss, mL	95±59	152±113	0.08
Pathology			1.00
Schwannoma	10	4	
Meningioma	5	3	
Rescue case	9 (60%)	1 (14%)	0.07

MMT, manual muscle test.

* Fisher's exact test. Emboldened fonts are statistically significant.


Patients with spinal cord tumor who underwent spine surgery using IONM (n=100) between 2014and2021
Exclusion by tumor location
IMSCT n=8
EDSCT n=18
CET n=23
Exclusion by Eden type
Eden Type III or IV Dumbbelltumor n=9
IDEMn=42
Exclusion by tissue
Ewing Sarcoma n=1
Meningocele n=1
Hemangioma n=1
n=39
Schwannoma n=25
Meningioma n=14

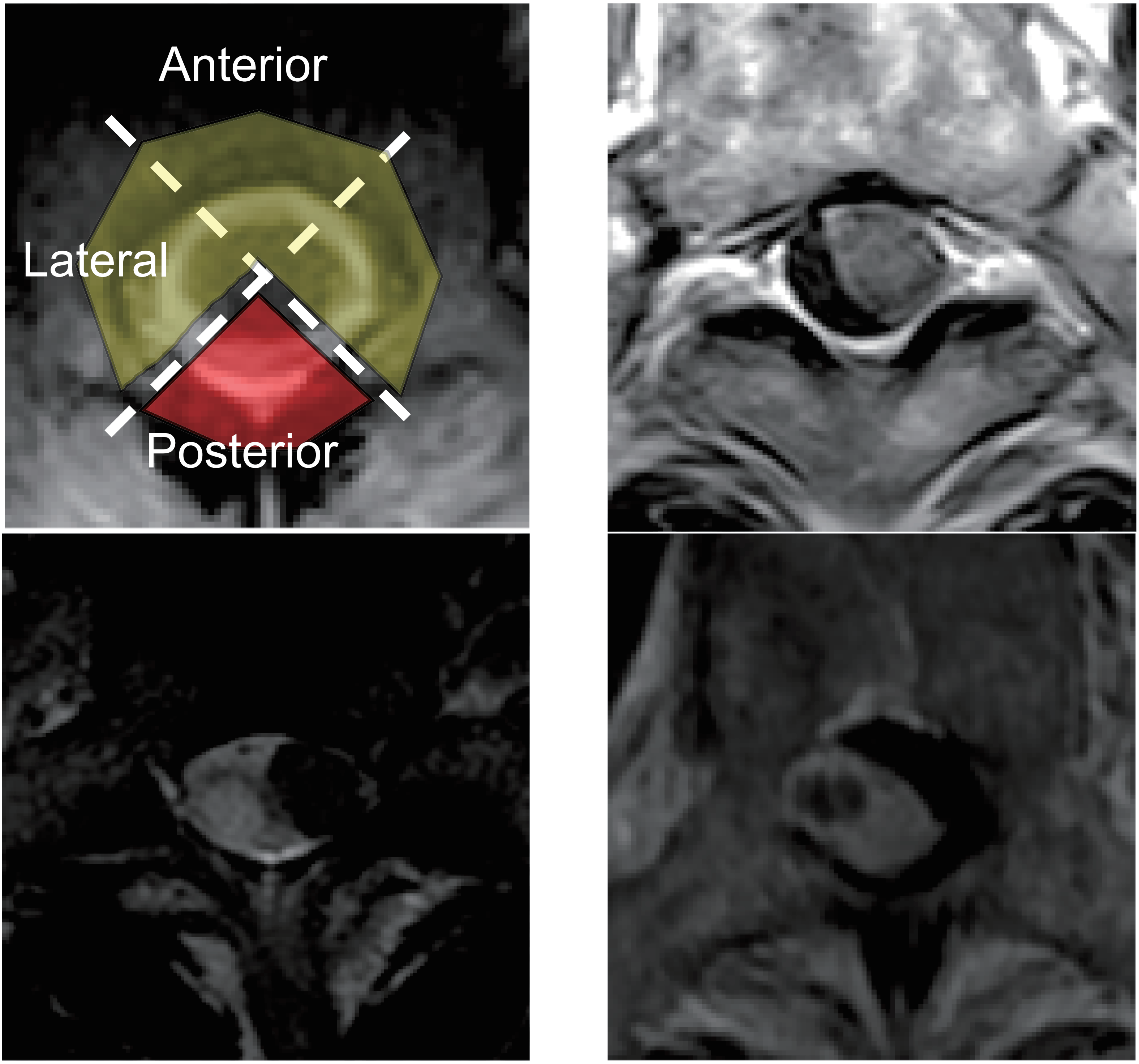

Anterior
Lateral
Posterior

Table 1. Comparison of baseline and surgical factors between the alert and non-alert groups

Variable	No. of patients (N=39)		p-value
	Alert group (n=22)	Non-alert group (n=17)	
Age, years	61±14	66±12	0.24
Sex			0.10
Male	12	4	
Female	10	13	
Preoperative neurological deficit			0.52
No deficit (MMT score of 5)	13	12	
Deficit (MMT score <5)	9	5	
Tumor level			1.00
Cervical	5	3	
Thoracic	17	14	
Tumor location			0.17
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4	52 / M	S	Anterolateral	Dural [illegible]	Cessation	No recovery	No	FP
5	51 / F	S	Posterior	Laminectomy	Cessation + BP elevation	No recovery	No	FP
6	39 / M	S	Anterolateral	Laminectomy	Cessation + BP elevation	No recovery	No	FP
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