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Multimodal Intraoperative Neuromonitoring in Intradural Spinal Tumors: A Detailed Case Series Highlighting the Role of D‑Wave Monitoring

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Case Report

Keywords: Intradural tumor, Intramedullary tumor, D‑wave, MEP, SSEP, Intraoperative neuromonitoring

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The authors declare no competing interests.

Ethics Approval: The study protocol was reviewed by the Institutional Ethics Committee of [Kokilaben Dhirubhai Ambani Hospital and Research Institute], and the requirement for formal ethical approval was waived due to the retrospective nature of the case series .

Consent to Participate and Publish: Written informed consent was obtained from the patients for participation in the study and for publication of clinical details and images.

Multimodal Intraoperative Neuromonitoring in Intradural Spinal Tumors: A Detailed Case Series Highlighting the Role of D-Wave Monitoring

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Abstract

Background:
Surgical management of intradural spinal tumors carries a significant risk of postoperative neurological deficits due to the compact organization of neural pathways within the spinal cord. Multimodal intraoperative neuromonitoring (IONM), including motor evoked potentials (MEP), somatosensory evoked potentials (SSEP), and D-wave monitoring, has emerged as an essential adjunct for functional preservation.

Objective:
To evaluate the role of multimodal IONM in guiding tumor resection and predicting postoperative neurological outcomes in patients undergoing surgery for intradural spinal tumors.

Methods:
A retrospective analysis of four patients undergoing intradural spinal tumor resection with multimodal IONM was performed. Intraoperative neuromonitoring changes were correlated with immediate and follow-up neurological outcomes.

Results:
Transient MEP changes were observed in three patients. Preservation or recovery of D-wave amplitude strongly correlated with favorable long-term motor outcomes.

Conclusion:
Multimodal IONM, particularly D-wave monitoring, plays a critical role in safe resection of intradural spinal tumors and in predicting postoperative neurological recovery.

Keywords: Intradural tumor, Intramedullary tumor, D-wave, MEP, SSEP, Intraoperative neuromonitoring

Introduction

Intradural spinal tumors, including intramedullary and extramedullary lesions, pose significant surgical challenges due to the narrow spinal canal and dense arrangement of ascending and descending neural tracts. Although gross total resection remains the primary surgical goal, preservation of neurological function is paramount.

Multimodal intraoperative neuromonitoring integrates MEP, SSEP, and D-wave monitoring to provide real-time functional assessment of corticospinal and sensory pathways. Among these modalities, D-wave monitoring has been shown to be the most reliable predictor of long-term motor outcomes because it directly reflects corticospinal tract conduction.

Methods

Study Design: Retrospective case series.

All patients underwent tumor resection under multimodal IONM including: - Transcranial motor evoked potentials (MEP) - Somatosensory evoked potentials (SSEP) of median and posterior tibial nerves - Epidural D-wave recording

Alert Criteria: - MEP amplitude reduction >50% - D-wave amplitude reduction >50% - Significant SSEP latency prolongation or amplitude reduction

Anesthesia Protocol: Total intravenous anesthesia with avoidance of long-acting neuromuscular blockade and maintenance of stable mean arterial pressure to optimize monitoring reliability.

Case Presentations

Case 1

A 26-year-old male presented with a D10–D12 intramedullary tumor. Intraoperatively, left lower limb MEP signals were lost during tumor resection while D-wave amplitude remained preserved. Immediate postoperative weakness (1/5) improved to 4/5 by postoperative day 5 with restoration of ambulation.

Figure 1: Preoperative MRI sagittal T2-weighted image showing intramedullary thoracic spinal tumor (Case 1).

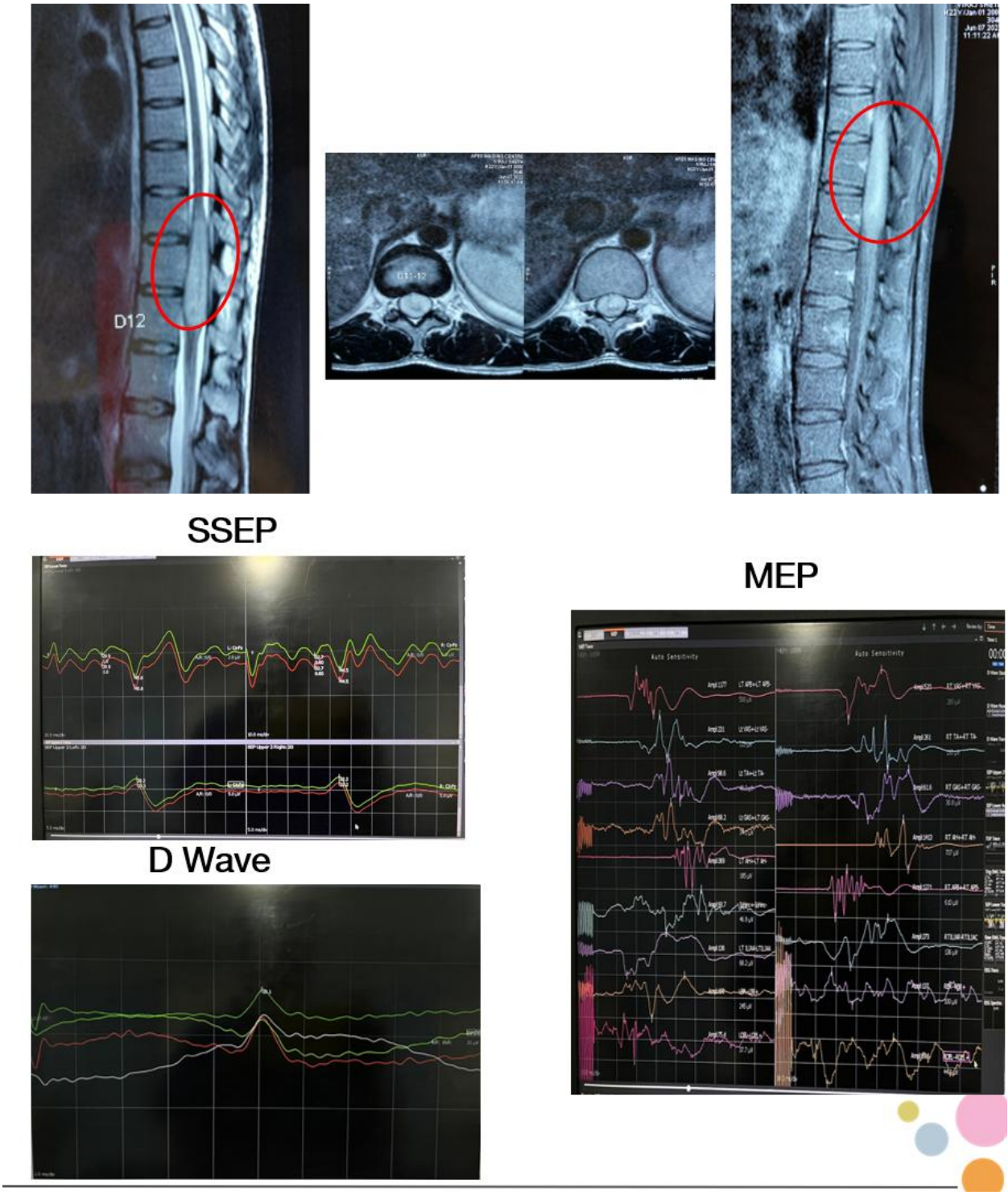


Figure 2 IONM trace showing MEP with D-wave amplitude

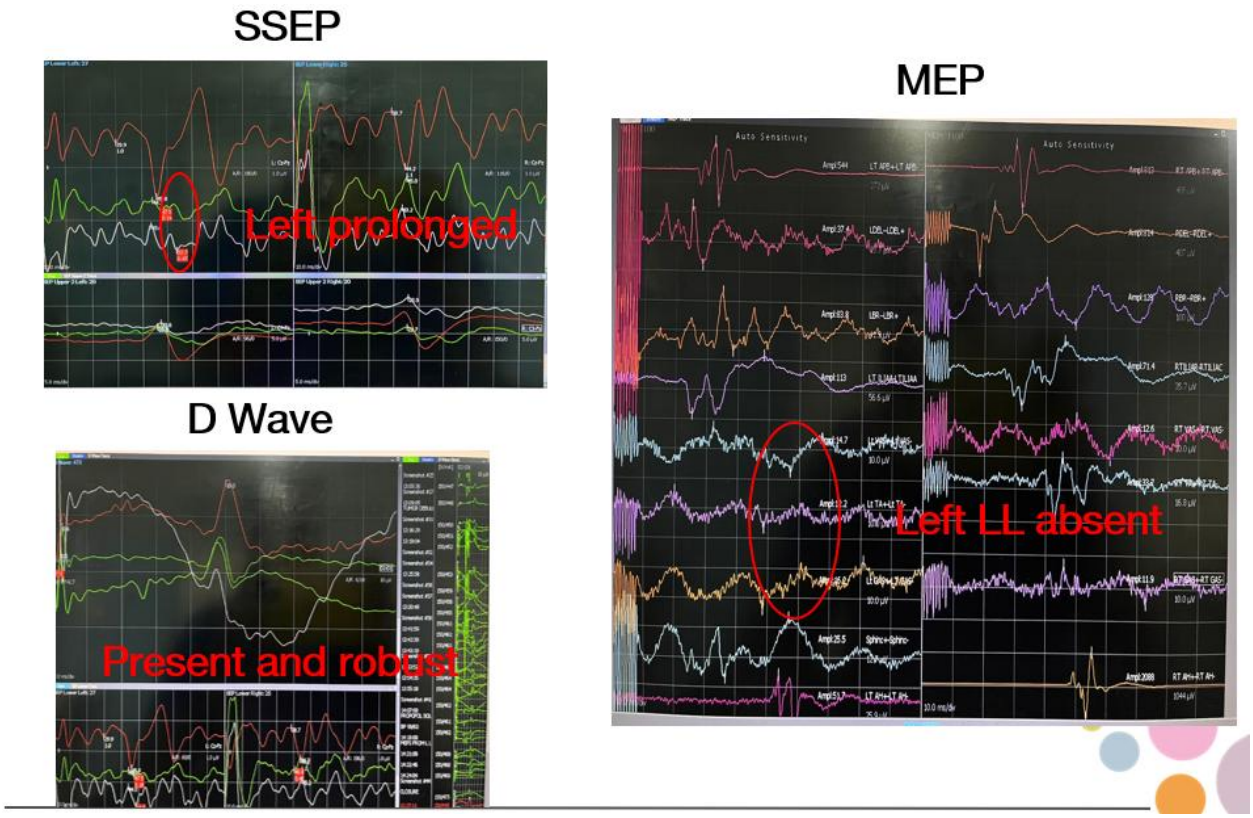
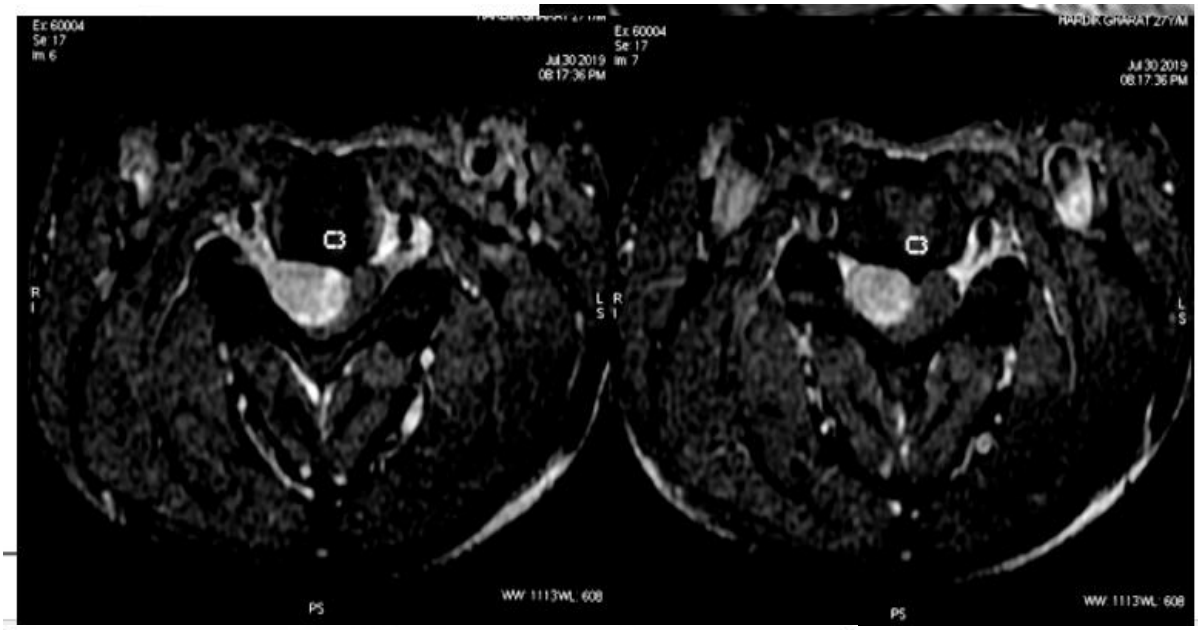


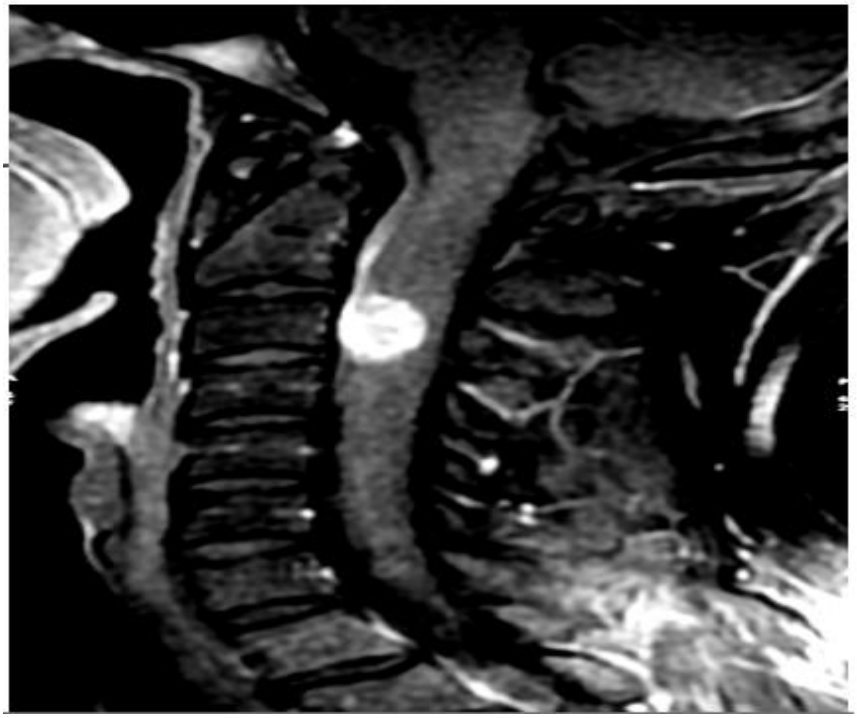
Figure3: IONM trace showing loss of MEP with preserved D-wave amplitude (Case 1).

Case 2

A 27-year-old male with a cervical intradural tumor demonstrated intraoperative reduction of left upper limb MEP amplitude to 50% with subsequent recovery to baseline. D-wave signals remained stable. No postoperative motor deficit was observed.

Figure 4: Preoperative cervical spine MRI demonstrating intradural lesion (Case 2).


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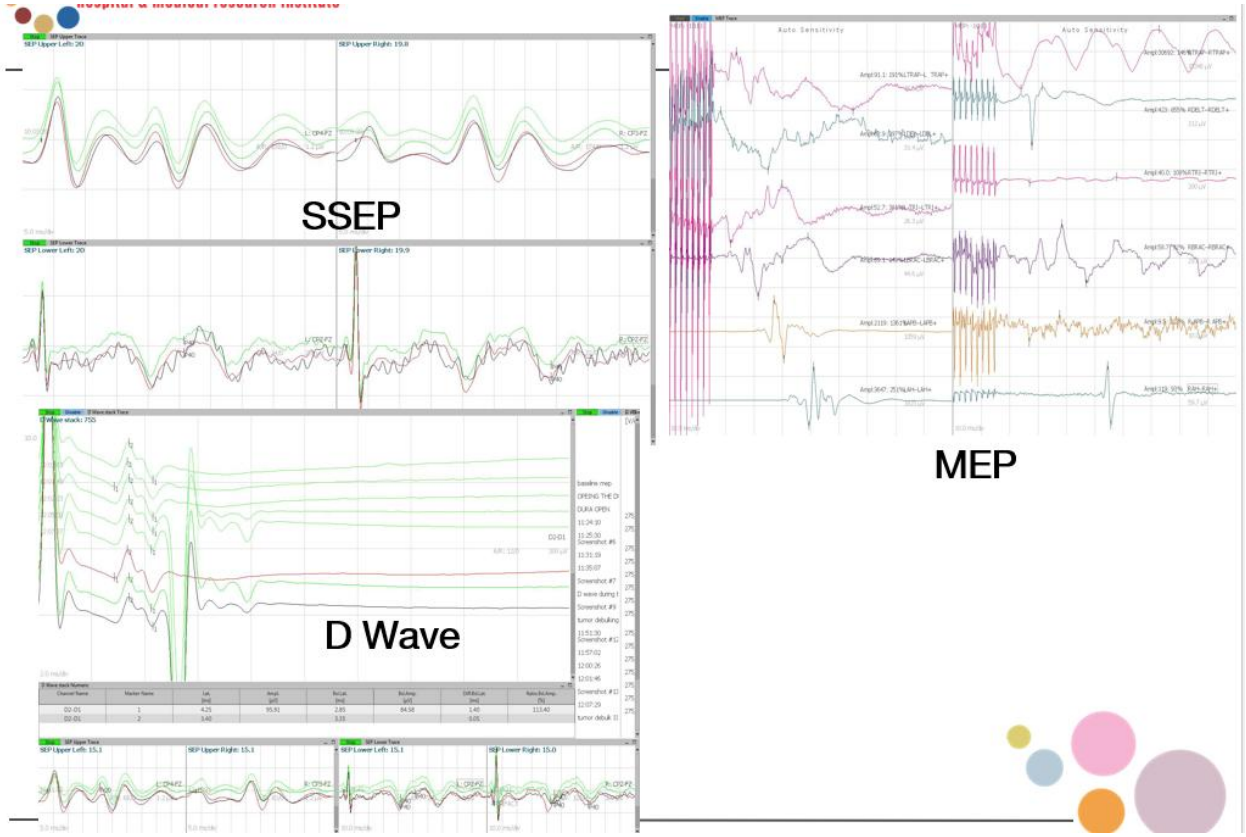


Figure 5: Stable D-wave recording throughout tumor excision

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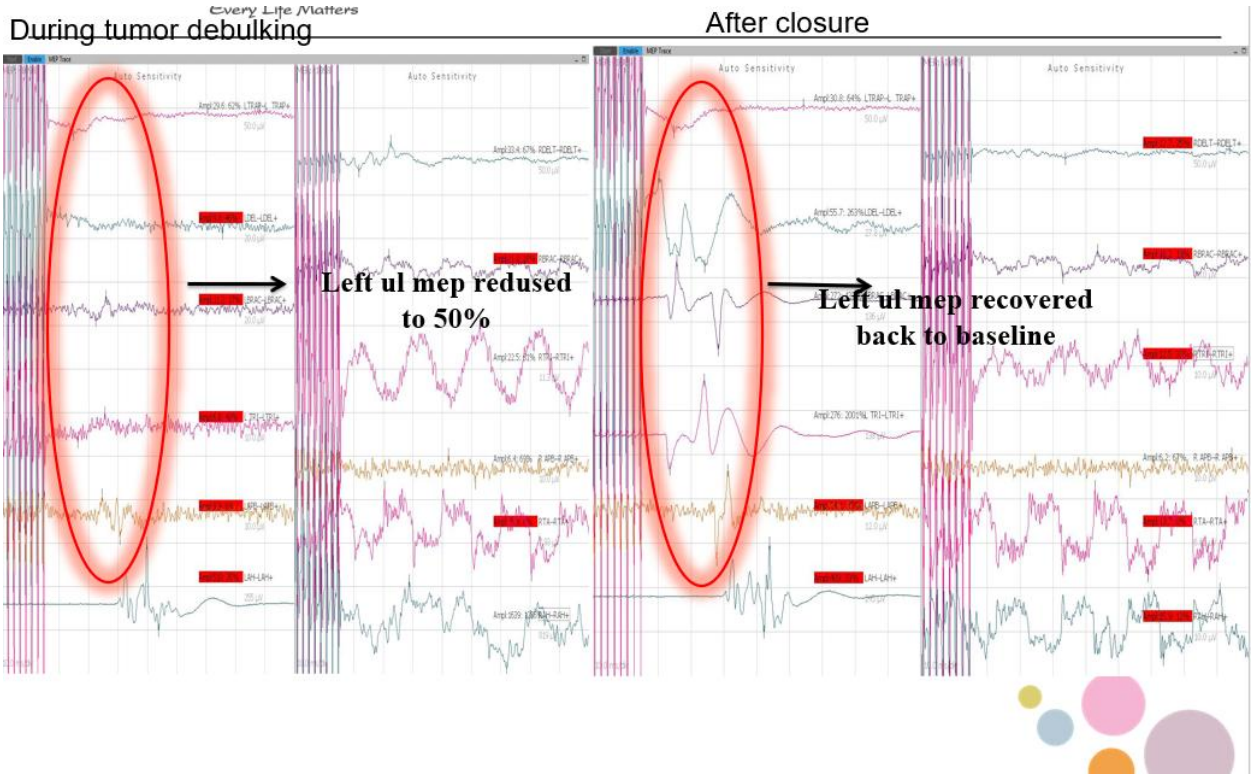


Figure 6: Intraoperative neuromonitoring recording showing transient MEP reduction

IMMEDIATE POST OP

GROUP	RIGHT UPPER LIMB	LEFT UPEER LIMB
SHOULDER	**3/5**	4+/5
ELBOW	4/5	4+/5
WRIST	4/5	4+/5

POST OP DAY 4

GROUP	RIGHT UPPER LIMB	LEFT UPEER LIMB
SHOULDER	**4/5**	4+/5
ELBOW	4+/5	4+/5
WRIST	4+/5	4+/5

POST OP MRI



Figure7: Postop MRI cervicothoracic spine showing excision of lesion and post operative power recorded

Case 3

A 38-year-old female with thoracic intramedullary schwannoma developed bilateral lower limb MEP reductions intraoperatively while D-wave signals were preserved. Postoperative transient sensory symptoms resolved within 25 days.



Figure 8: Preoperative MRO showing thoracic intramedullary schwannoma

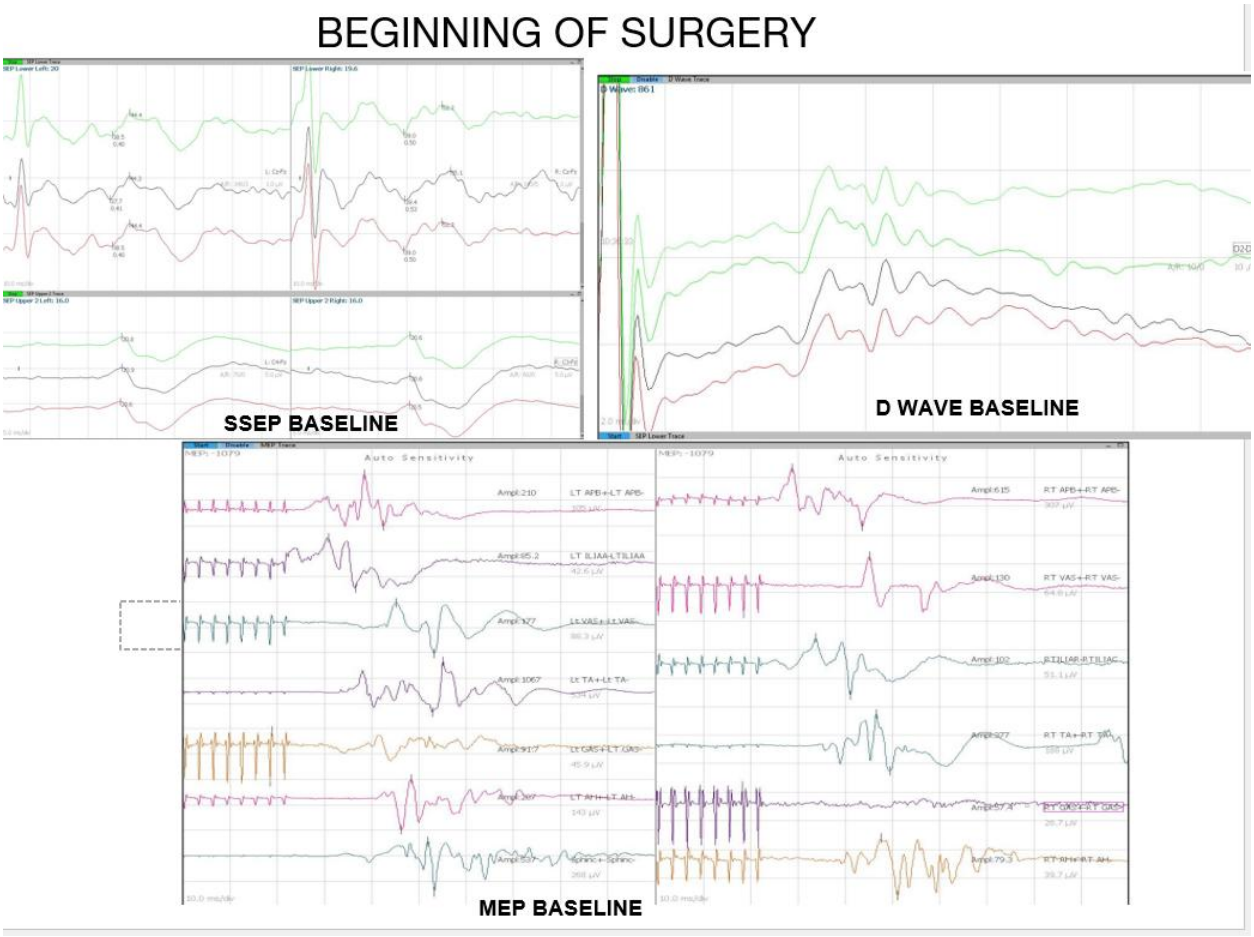


Figure 9 : Intraoperative neuromonitoring showing SSEP, D wave and MEP baseline

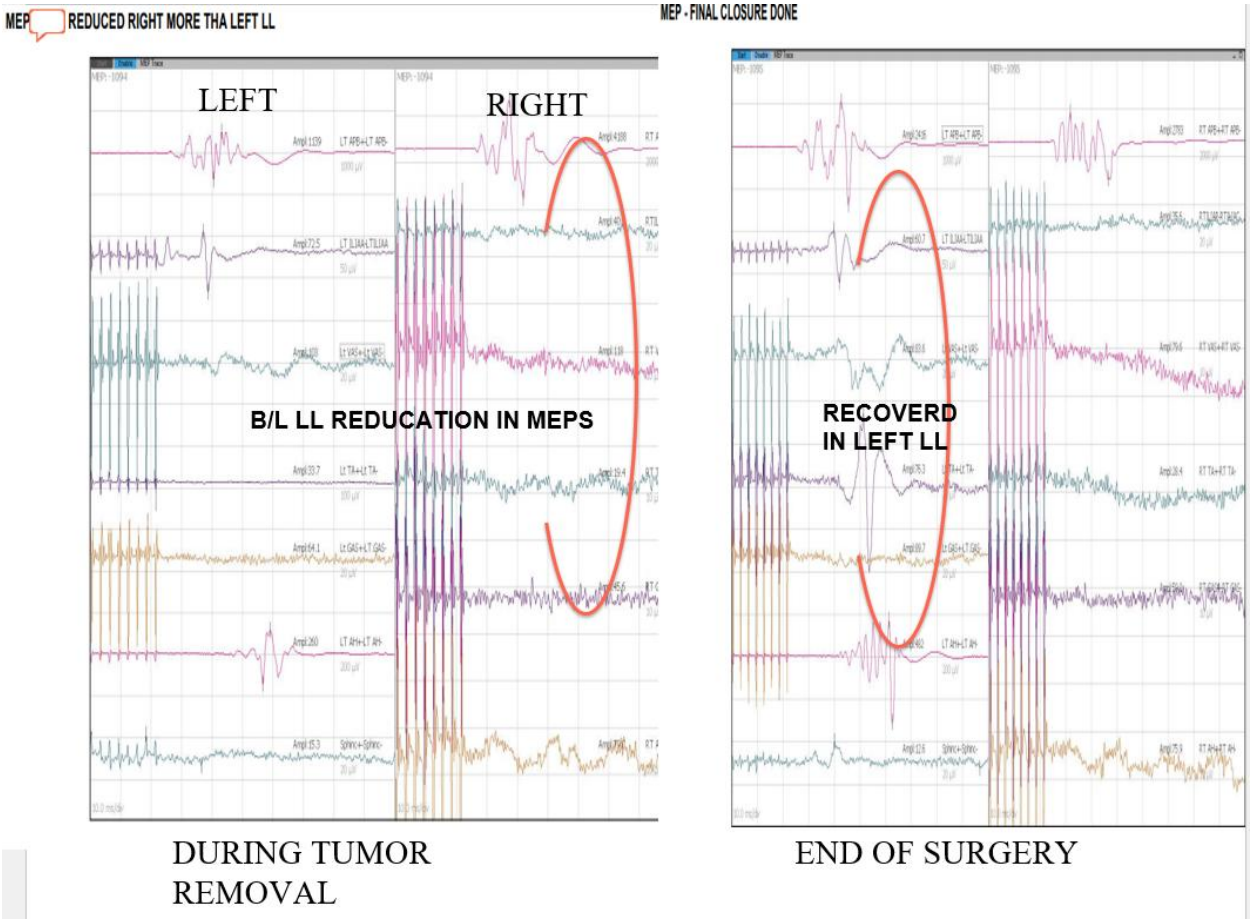


Figure 10: Intraoperative neuromonitoring showing bilateral reduction in MEP and recovered MEP in left LL.



Immediate post op

	Group	Right LL	Left LL
motor	HIP	4-/5	4/5
	KNEE	4-/5	4+/5
	ANKLE	4/5	4+/5
sensory	**touch**	**reduced**	**normal**
	pain	**Slightly reduced**	normal
	temperature	normal	normal

Figure 11: Postoperative MRI showing excision of lesion and power recorded.

Case 4

A 9-year-old boy with a thoracic low-grade glial tumor developed bilateral reduction in motor evoked potentials (MEPs) along with a decrease in D-wave amplitude to approximately 50% during tumor debulking. With intraoperative adjustments, the D-wave amplitude gradually recovered to nearly 80% of the baseline by the time of wound closure. Postoperatively, the patient exhibited motor weakness that improved significantly by the time of discharge.

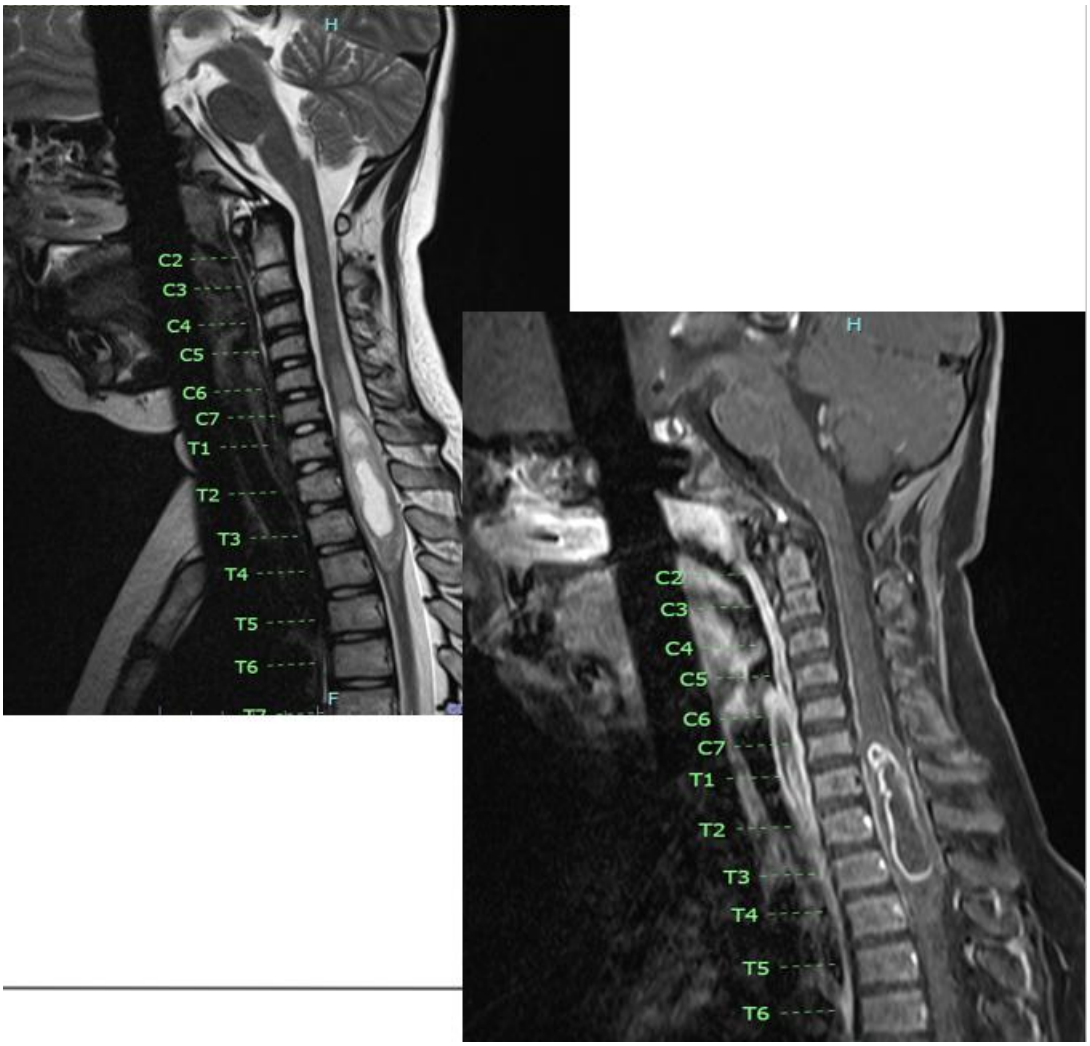


Figure 12: Pediatric thoracic spinal tumor on preoperative MRI (Case 4).

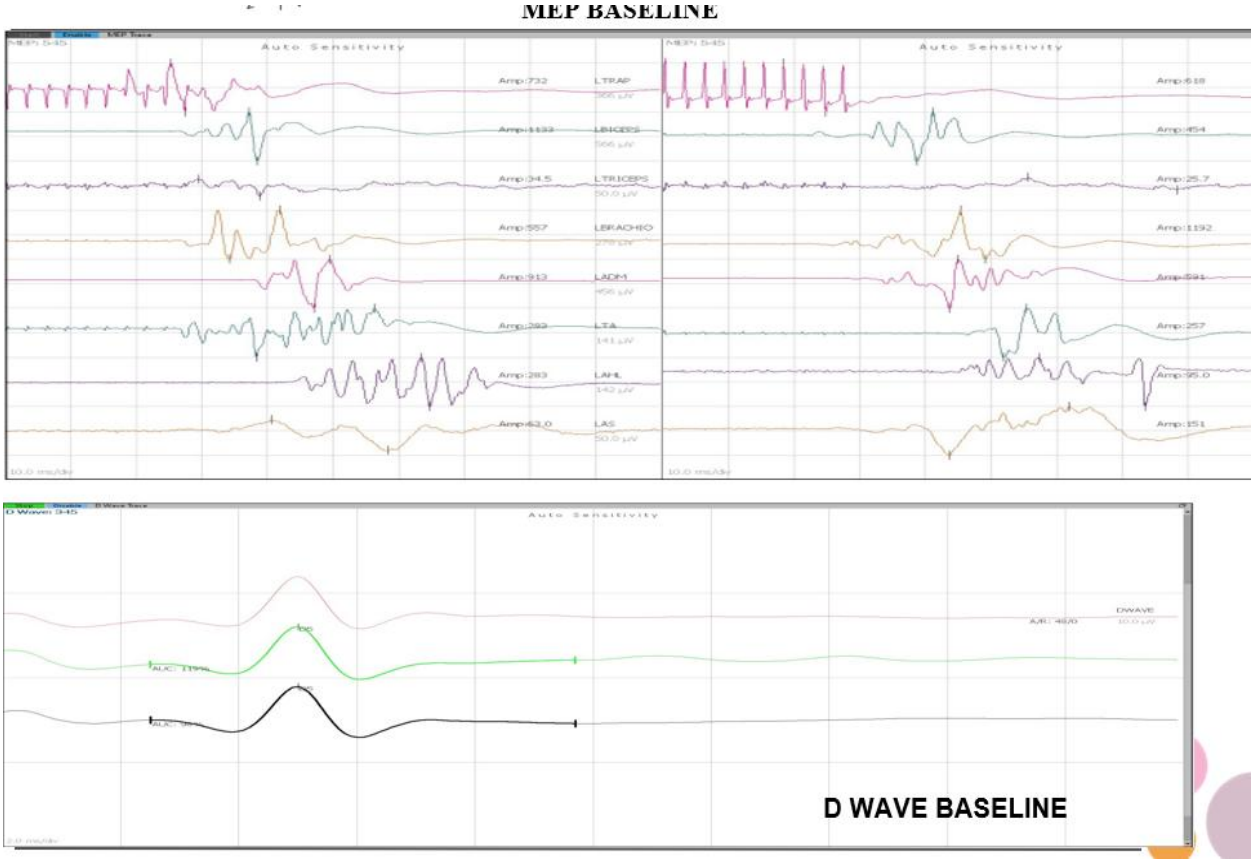


Figure 13: Intraoperative neuromonitoring showing MEP and D wave baseline.

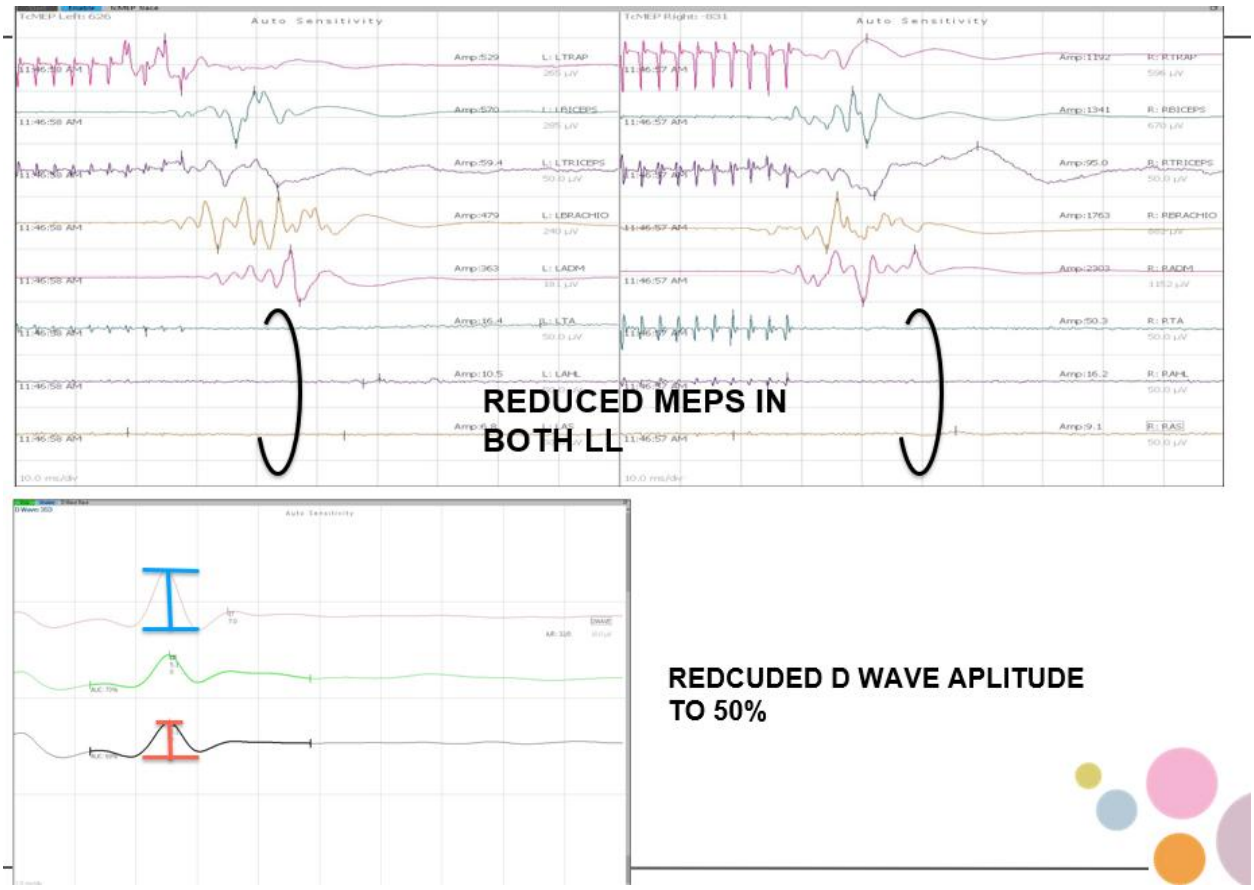


Figure 14: Intraoperative neuromonitoring showing reduce MEP in both lower limb and reduce D wave aplitude to 50%.

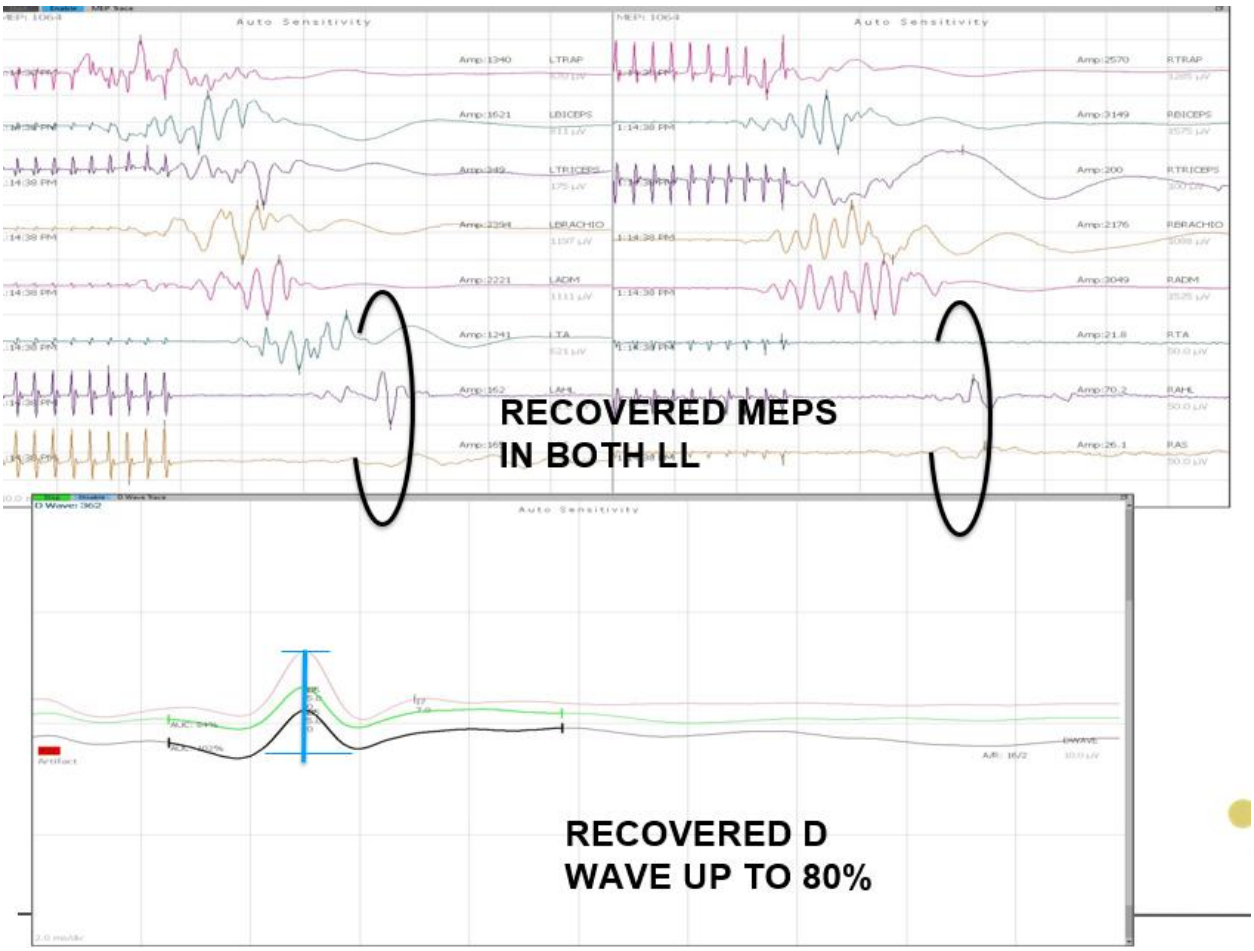


Figure 15: Reduced MEP in both LL and reduce D wave to 80 %.



Figure 16 : Post operative MRI Cervicothoracic spine showing excision of lesion and post operative changes

Results

Preservation or recovery of D-wave amplitude across cases demonstrated a strong correlation with favorable postoperative motor outcomes. In instances where transient loss of motor evoked potentials (MEPs) occurred without a sustained decline in D-wave amplitude, neurological deficits were typically temporary and showed subsequent recovery. These findings highlight the complementary role of D-wave monitoring in distinguishing reversible intraoperative corticospinal tract disturbances from permanent injury.

Discussion

Intradural spinal tumor surgery carries significant risk because of manipulation of delicate neural structures, particularly the corticospinal tracts. Multimodal intraoperative

neurophysiological monitoring (IONM) has therefore become a key strategy for reducing postoperative neurological morbidity and improving surgical safety.[1]

Motor evoked potential (MEP) monitoring provides real-time assessment of corticospinal tract integrity and allows early detection of motor pathway compromise during tumor resection. However, MEP signals are highly sensitive to anesthetic depth, hypotension, temperature fluctuations, and transient surgical manipulation. Consequently, isolated MEP loss may not necessarily indicate irreversible neurological injury.[2,4]

D-wave monitoring records direct corticospinal tract volleys through epidural electrodes and is relatively resistant to anesthetic influences and neuromuscular blockade, making it a more stable indicator of corticospinal tract integrity.[5] Preservation of **≥50% of baseline D-wave amplitude** has consistently been associated with favorable long-term motor outcomes, even in situations where muscle MEPs transiently disappear.[3] Recent studies further demonstrate that D-wave changes are strong independent predictors of long-term postoperative motor dysfunction during intramedullary spinal cord tumor surgery.[6]

The addition of somatosensory evoked potential (SSEP) monitoring complements motor pathway monitoring by evaluating dorsal column function. Multimodal interpretation of MEPs, SSEPs, and D-waves enables simultaneous assessment of sensory and motor tracts, improving intraoperative decision-making and reducing the risk of permanent neurological deficit.[7]

Recent evidence suggests that integration of D-wave monitoring within multimodal IONM improves the ability to continue tumor resection safely after transient MEP loss, facilitating maximal safe tumor removal while maintaining functional outcomes.[8]

This case series highlights several important clinical implications:

1. Transient MEP loss alone should not mandate termination of tumor resection if D-wave signals remain preserved.[6]
2. D-wave monitoring allows surgeons to proceed with cautious tumor debulking while maintaining corticospinal tract integrity.[3]
3. Interpretation of multimodal neuromonitoring signals rather than reliance on a single modality is essential for optimal intraoperative decision-making.[1]

The main limitations of this study include the small sample size and retrospective design. Larger prospective multicenter studies are needed to establish standardized alarm criteria and predictive models for neurological outcomes following intradural spinal tumor surgery.

Conclusion

Multimodal intraoperative neuromonitoring plays a crucial role in enhancing surgical safety during intradural spinal tumor resection by providing real-time assessment of neural

pathway integrity. Among the available modalities, preservation of D-wave amplitude serves as one of the most reliable predictors of postoperative motor function. Incorporation of D-wave monitoring alongside motor evoked potentials and somatosensory evoked potentials can aid in distinguishing reversible intraoperative changes from true corticospinal tract injury. Therefore, whenever technically feasible, D-wave monitoring should be routinely utilized during intramedullary spinal cord tumor surgery to optimize neurological outcomes.

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Ethics Approval and Consent to Participate

This study was conducted in accordance with the ethical standards of the institutional and national research committee and with the principles of the Declaration of Helsinki. Formal ethics committee approval was not required for this work as it represents a retrospective clinical observation/case-based report without patient identifiers.

Patient Consent
Written informed consent for publication of clinical details and images was obtained from the patient/guardian.

Conflict of Interest
The authors declare that they have no conflict of interest.

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Author Contributions
All authors contributed to the conception, data collection, analysis, manuscript drafting, and final approval of the manuscript.

Data Availability Statement
Data supporting the findings of this study are available from the corresponding author upon reasonable request.