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Advanced Case Report: Challenges and Innovations in Intraoperative Neuro monitoring for a Complex Neurovascular Tumour Resection

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Abstract

Intraoperative neuromonitoring (IONM) is a cornerstone in reducing neurological deficits during complex neurosurgical procedures. However, extreme cases involving neurovascular tumors with proximity to critical structures like the brainstem, cranial nerves, and cortical motor areas present unique challenges. This case report explores the successful application of multimodal IONM in a patient undergoing resection of a cavernous sinus meningioma with encasement of the internal carotid artery (ICA), involvement of cranial nerves III–VI, and cortical-spinal tract (CST) compression. We highlight technical obstacles, adaptive strategies, and the integration of emerging technologies, emphasizing their impact on optimizing surgical outcomes and preventing catastrophic complications.

Keywords

Intraoperative Neuromonitoring, Neurovascular Tumor, Cavernous Sinus Meningioma, Motor Evoked Potentials, Cranial Nerve Monitoring, Advanced IONM Strategies, Neurosurgery.

Introduction

Cranial base tumors often present formidable challenges due to their location, size, and involvement of eloquent neurovascular structures. The integration of IONM, including somatosensory evoked potentials (SSEPs), motor evoked potentials (MEPs), brainstem auditory evoked potentials (BAEPs), and direct cranial nerve monitoring, is pivotal for reducing intraoperative risks. Despite technological advancements, extreme cases with anatomical distortion, electrical signal attenuation, and high susceptibility to physiological variables necessitate exceptional expertise and adaptability.

This report describes the most challenging intraoperative case of neuromonitoring in our institution, showcasing the interplay of advanced modalities, real-time problem-solving, and interdepartmental collaboration to achieve a successful outcome.

Case Presentation

Patient Profile: A 47-year-old female presented with progressive diplopia, facial numbness, and intermittent headaches over two years. Imaging revealed a large cavernous sinus meningioma (4.5 cm) compressing the CST, encasing the ICA, and extending into Meckel's cave. Significant cranial nerve (CN) involvement (III, IV, V1/V2, and VI) was evident. The surgical goal was maximal safe resection while preserving neurovascular integrity.

Preoperative Preparation

1. **Neurological Baseline Assessment:**

• Cranial nerve deficits: Complete left abducens (CN VI) palsy, partial CN V2 sensory loss.
• Motor strength intact; subtle CST compression signs.
• BAEPs baseline confirmed mild auditory delay on the left.

2. **IONM Strategy:**

• Multimodal monitoring included:
• MEPs: Transcranial electrical stimulation for CST monitoring.
• SSEPs: Median and tibial nerve stimulation to monitor sensory pathways.
• BAEPs: Continuous auditory pathway monitoring.
• CN Mapping: Direct stimulation of CN III, IV, V, and VI.
• Electrocorticography (ECoG): Cortical activity mapping for potential seizure thresholds.

3. **Technological Innovations:**

• High-Density Electrode Arrays: Enhanced spatial resolution for cortical and cranial nerve mapping.
• Neuronavigation-IONM Integration: Real-time feedback between imaging and electrophysiology.

Intraoperative Challenges

1. **Anatomical and Electrophysiological Complexity**

• Severe signal attenuation was observed due to tumor-induced CST compression and brainstem displacement.
• Electrical interference from adjacent cranial nerve signals caused overlapping potentials, complicating CN-specific monitoring.

2. Physiological Perturbations

• Intraoperative hypotension transiently compromised perfusion, leading to MEP amplitude reduction and prolonged SSEP latencies.
• Temperature fluctuations affected BAEP waveforms, necessitating aggressive thermal regulation.

3. Surgical Maneuver-Induced Signal Loss

• ICA mobilization resulted in abrupt MEP signal loss, triggering immediate suspension of tumor resection.
• Sustained traction near CN VI caused complete cessation of its electrophysiological signals, demanding intraoperative nerve sheath exploration.

Innovative Solutions and Real-Time Adaptations

1. **Signal Optimization:**

• Adjusted stimulation parameters (increased pulse duration and intensity) for clearer MEP/SSEP acquisition.

• Implemented advanced filtering techniques to reduce noise and interference.

2. **Collaborative Problem-Solving:**

• Immediate coordination with anesthesiology to normalize systemic blood pressure, restoring MEPs within minutes.

• Neurosurgical pause with irrigation around CN VI resolved nerve conduction block.

3. **Neuroprotective Interventions:**

• Applied neuroprotective agents (e.g., methylprednisolone) locally to mitigate neural inflammation during traction-induced deficits.

4. **Emerging Technology Deployment:**

• **Near-Infrared Spectroscopy (NIRS):** Provided additional brain oxygenation metrics, correlating physiological compromise with electrophysiological changes.

• **Dynamic Motor Threshold Mapping:** Helped recalibrate CST monitoring thresholds intraoperatively.

Outcome and Follow-Up

Postoperatively, the patient experienced transient worsening of CN VI palsy but retained motor and sensory functions. MRI confirmed gross-total resection with preserved ICA flow. At the 6-month follow-up, the patient exhibited improved CN VI function and complete recovery of facial sensation.

Discussion

This case underscores the indispensable role of multimodal IONM in mitigating neurological risks during complex neurovascular surgeries. Critical factors influencing success included:

• Real-time adaptations to physiological changes and anatomical challenges.

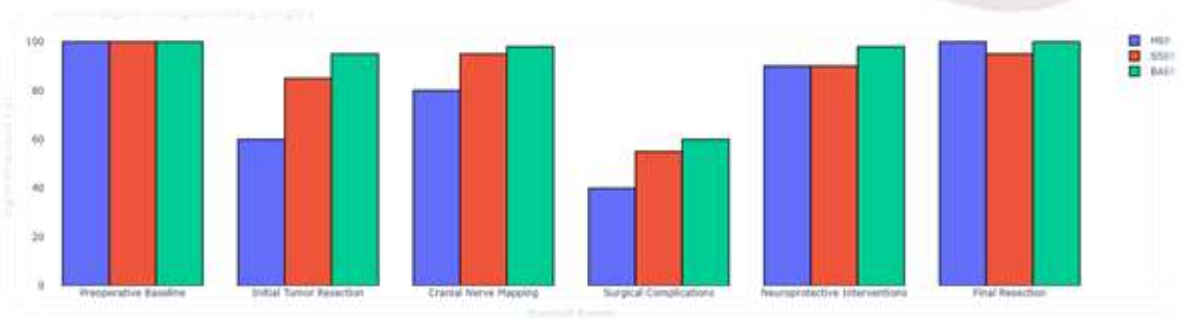
• Integration of cutting-edge technology for enhanced signal fidelity.

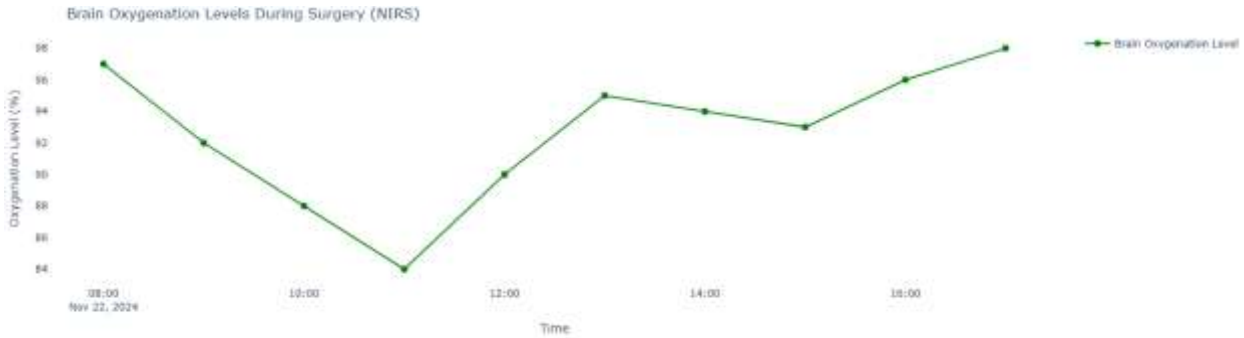
• Multidisciplinary collaboration.

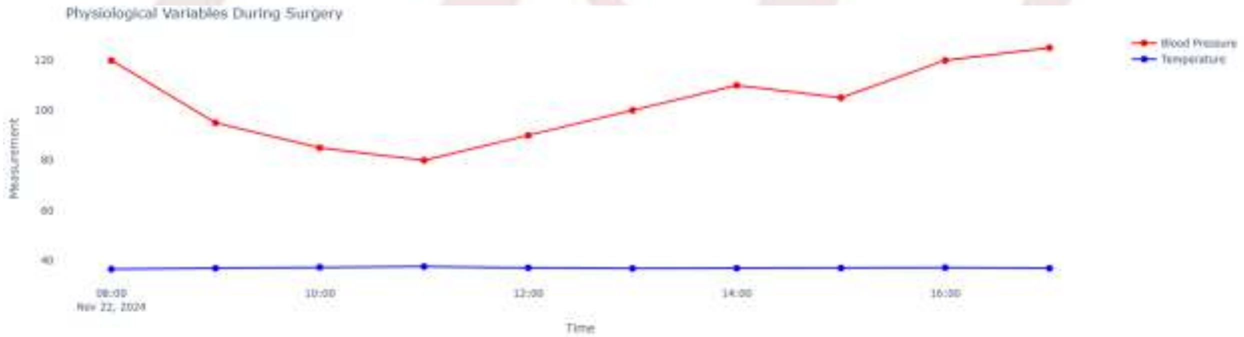
The deployment of neuronavigation-integrated IONM and high-density mapping arrays illustrates the potential of advanced tools in navigating the most extreme cases. Future innovations, such as AI-driven signal prediction and robotic neurosurgery, hold promise for further reducing operative risks.

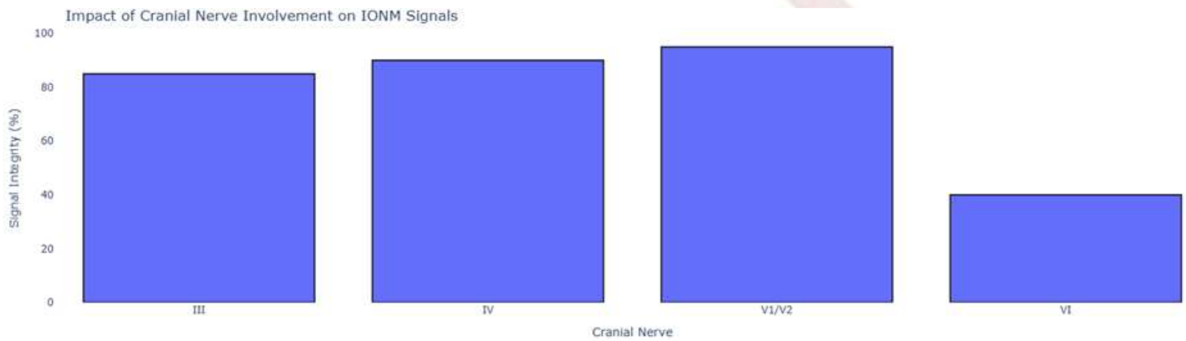
Conclusion

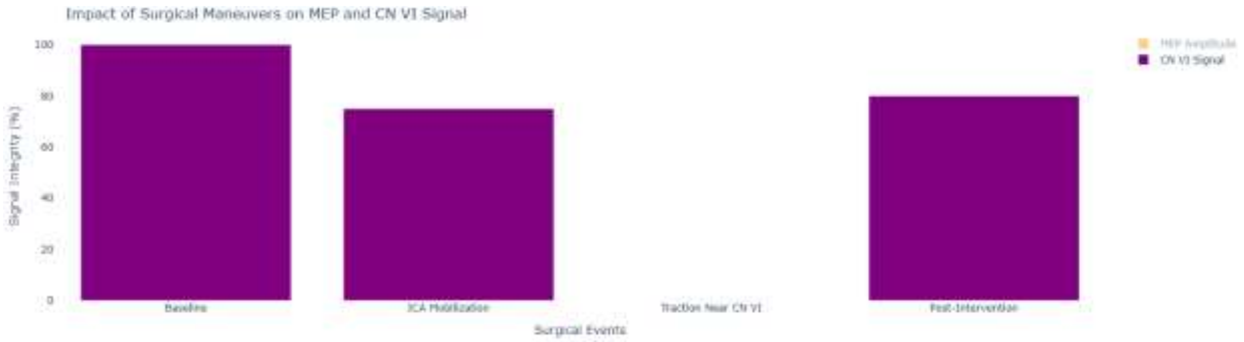
This case exemplifies the pinnacle of IONM complexity, showcasing its transformative impact on neurosurgical outcomes when confronted with extreme challenges. Advanced tools and adaptive strategies are essential in pushing the boundaries of safe resection in neurosurgery.




Brain Oxygenation Levels During Surgery (NIRS)
Brain Oxygenation Level
Oxygenation Level (%)
08:00
Nov 22, 2024
10:00
12:00
14:00
16:00
Time


Physiological Variables During Surgery
Blood Pressure
Temperature
Measurement
120
100
80
60
40
08:00
Nov 22, 2024
10:00
12:00
14:00
16:00
Time


Impact of Cranial Nerve Involvement on IONM Signals
Signal Integrity (%)
100
80
60
40
20
0
III
IV
V1/V2
VI
Cranial Nerve



1. **Physiological Variables (Blood Pressure and Temperature):**

• Tracks the fluctuations in blood pressure and temperature during the surgery, showing how these physiological variables might influence IONM signal integrity.

2. **Cranial Nerve Involvement:**

• Illustrates the impact of cranial nerve involvement (III–VI) on IONM signal integrity. It helps highlight how specific nerves are affected during the procedure and may require adjustments in monitoring.

3. **Surgical Maneuver Impact:**

• Shows how certain surgical maneuvers, such as ICA mobilization or traction near CN VI, influence MEP and CN VI signals, emphasizing the real-time response of IONM.

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