



REAL-TIME MULTIMODAL NEUROMONITORING DURING UNILATERAL BIPORTAL ENDOSCOPIC LUMBAR SURGERY: A SINGLE-CENTER SAFETY ANALYSIS

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ABSTRACT

Objective: Lumbar discectomy and decompression using unilateral biportal endoscopy (UBE) have become increasingly adopted minimally invasive techniques in spine surgery. Nevertheless, intraoperative neural irritation may occur due to procedure-related factors and the technical learning curve. This study aimed to describe intraoperative electrophysiological findings obtained with multimodal neuromonitoring during lumbar surgery performed using UBE, with particular attention to free-running electromyographic activity associated with electrocautery use.

Materials and Methods: A retrospective analysis was performed on 78 patients who underwent lumbar discectomy or decompression using UBE between January 2024 and June 2025. The multimodal intraoperative neuromonitoring (IONM) protocol consisted of free-running electromyography (freeEMG), motor evoked potentials (MEP), and somatosensory evoked potentials (SEP).

Results: FreeEMG activity temporally associated with electrocautery use was observed in 32 of 78 patients (41.0%). In these cases, the electrocautery power was reduced intraoperatively, after which the freeEMG activity returned to baseline. Among 18 patients with preoperative motor weakness, postoperative improvement was observed in 14. No new postoperative neurological deficits were identified.

Conclusion: Multimodal IONM provided real-time electrophysiological information during lumbar surgery performed using UBE. FreeEMG activity was observed in temporal association with electrocautery use and returned to baseline after modification of the electrocautery settings. These findings are descriptive and do not establish a protective effect of IONM. Prospective controlled studies are needed to determine whether such intraoperative feedback translates into improved neurological outcomes.

Keywords: Unilateral biportal endoscopy, intraoperative neuromonitoring, freeEMG, motor evoked potentials, somatosensory evoked potentials

INTRODUCTION

Lumbar surgery using unilateral biportal endoscopy (UBE) has become an increasingly preferred minimally invasive treatment option for lumbar degenerative disorders because of smaller incisions, reduced soft tissue injury, and favorable postoperative recovery profile. However, intraoperative and postoperative complications may still occur, particularly due to the technical learning curve associated with UBE and the increasing number of elderly patients presenting with degenerative spinal pathology related to prolonged life expectancy⁽¹⁻³⁾. The close proximity of surgical instruments to neural structures, limitations inherent to endoscopic visualization, and potential thermal irritation or injury associated with coagulation devices may further increase the risk of complications^(1,2,4,5). Therefore, the development and implementation of intraoperative safety

strategies during procedures using UBE remain of considerable importance^(1,6).

Intraoperative neuromonitoring (IONM) is widely used in spinal surgery to establish baseline neurological function at the beginning of surgery and to detect intraoperative changes in neural integrity^(4,7,8). Multimodal IONM approaches are commonly preferred because they allow simultaneous assessment of different neural pathways^(7,8). Somatosensory evoked potentials (SEP) and motor evoked potentials (MEP) provide information regarding the functional integrity of sensory and motor tracts, whereas electromyography (EMG)-based techniques can offer immediate feedback during neural irritation or following direct and indirect nerve stimulation⁽⁹⁻¹²⁾.

In endoscopic lumbar procedures, early detection of intraoperative neural irritation through free-running EMG (freeEMG) may provide immediate electrophysiological

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feedback and allow the surgical team to reassess ongoing manipulation or operative parameters^(7,9,10,13).

Based on these considerations, the present study aimed to describe intraoperative electrophysiological observations obtained with multimodal IONM during lumbar discectomy and decompression with UBE. Particular attention was given to freeEMG activity occurring during electrocautery use and to changes in these recordings following adjustment of the electrocautery settings. The study was designed to characterize these intraoperative observations rather than to assess the clinical effectiveness of IONM.

MATERIALS AND METHODS

Between January 2024 and June 2025, a total of 78 patients who underwent lumbar discectomy or decompression using UBE without fusion or instrumentation at our institutions were retrospectively reviewed. The study was approved by the Hitit University Local Ethics Committee (approval no: 2025-124, date: 03.06.2025). Owing to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee.

Inclusion Criteria

1. Patients with symptomatic lumbar disc herniation or lumbar spinal stenosis requiring lumbar discectomy or decompression using UBE.
2. Single- or two-level lumbar degenerative pathology treated using UBE.
3. Availability of multimodal IONM (freeEMG, MEP, and SEP) throughout the procedure.
4. Complete perioperative clinical, neurological, and IONM records.
5. Availability of postoperative neurological follow-up.

Exclusion Criteria

1. Multilevel pathology requiring treatment at more than two lumbar levels.
2. Spinal deformity requiring corrective surgery.
3. Radiographic instability or spondylolisthesis requiring instrumented fusion.
4. Patients undergoing concomitant fusion or instrumentation.
5. Spinal infection, tumor, trauma, or other non-degenerative spinal pathology.
6. Incomplete clinical or postoperative follow-up data.
7. Inadequate IONM setup or incomplete neuromonitoring documentation.

Surgical Procedure

All patients underwent surgery according to standard unilateral biportal endoscopic surgical techniques. Decompression alone was performed in 22 patients, whereas 56 patients underwent discectomy. Continuous saline irrigation and clear endoscopic visualization were maintained throughout all stages of decompression and/or discectomy. Electrocautery was used

when necessary for hemostasis and for the management of soft tissues adjacent to the decompression area.

Anesthesia and Neuromonitoring

All procedures were performed under general anesthesia. During intubation, propofol and rocuronium were administered for induction and muscle relaxation. Anesthesia maintenance was achieved using remifentanyl and propofol. Except for the neuromuscular blockade administered during intubation, no additional muscle relaxants were used throughout the intraoperative period.

The multimodal IONM protocol consisted of the following components:

- Continuous freeEMG for real-time detection of spontaneous nerve root activity;
 - MEP recorded from representative upper- and lower-extremity muscles, including the abductor pollicis brevis, rectus femoris, extensor hallucis longus, and abductor hallucis, according to the operative level;
 - SEP for continuous assessment of sensory pathway integrity.
- Preoperative and postoperative motor strength was assessed from the neurological examinations documented in the clinical records. Postoperative motor improvement was based on documented improvement in muscle strength during follow-up rather than on an assessment at a predefined postoperative time point. Baseline MEP and SEP recordings were obtained at the beginning of surgery. During the intraoperative period, continuous multimodal IONM was applied, including ongoing freeEMG surveillance with additional SEP and MEP assessments when required. Changes in MEP and SEP recordings were assessed qualitatively during surgery; amplitude and latency changes were not systematically quantified for retrospective analysis. Free-running EMG activity was interpreted in real time by the same neuromonitoring specialist throughout all procedures. Repetitive or sustained EMG discharges occurring in temporal association with surgical manipulation or electrocautery use were recorded as intraoperative freeEMG events. No predefined quantitative thresholds for discharge duration, frequency, amplitude, or number had been prospectively established. In addition, a reliable distinction between neural irritation and electrocautery-related artifact could not be made retrospectively. Therefore, these events were described as freeEMG activity temporally associated with electrocautery use rather than as confirmed nerve root irritation or neural injury. When sustained or repetitive freeEMG activity was observed, the surgical maneuver and electrocautery settings were reassessed before the procedure was continued. Electrocautery was initially used at 35-40 W and was reduced to 15-20 W when such activity occurred during its use. FreeEMG activity was subsequently observed until it returned to baseline. This adjustment represented an intraoperative response to the electrophysiological finding and was not based on a prospectively defined study protocol.

Statistical Analysis

Descriptive statistical methods were used to summarize the study population and intraoperative findings. Continuous variables are presented as mean $\pm$ standard deviation and range, where available, whereas categorical variables are presented as numbers and percentages. Given the retrospective, single-cohort design and the absence of an unmonitored comparison group, the analyses were primarily descriptive. Clinical and operative characteristics were summarized according to the type of surgical procedure and intraoperative electrophysiological findings. No analysis was intended to determine the independent effect of IONM on postoperative neurological outcomes.

RESULTS

Patient Population

A total of 78 patients who underwent surgery with UBE were included in the study. Demographic characteristics such as age and sex, as well as clinical parameters including spinal pathology type, pathological level, and postoperative complications, were retrospectively evaluated from patient records.

Of the patients, 42 were female and 36 were male. The mean age was 57.3 years (range, 35-78 years). Lumbar disc herniation was identified in 56 patients, whereas 22 patients presented with lumbar spinal stenosis. Preoperative motor weakness was present in 18 cases. The demographic and clinical characteristics of the study population are summarized in Table 1.

Intraoperative Findings

Decompression alone was performed in 22 patients, while 56 patients underwent discectomy. Multimodal IONM with freeEMG, MEP, and SEP was used in all cases. Qualitative changes

in MEP and SEP recordings were observed during surgery; however, these changes were not systematically quantified or analyzed across the study population. Figures 1 and 2 show representative examples of MEP and SEP recordings obtained before and after discectomy and are presented for illustrative purposes.

FreeEMG activity temporally associated with electrocautery use was observed in 32 of 78 patients (41.0%) (Figure 3). In these cases, the electrocautery power was reduced intraoperatively, after which the freeEMG activity returned to baseline. No corresponding new postoperative neurological deficit was identified in these patients.

Postoperative Findings

The mean postoperative follow-up period was 17.4 $\pm$ 8.5 months. No new postoperative neurological deficits were observed during follow-up. Among the 18 patients with preoperative motor weakness, improvement in muscle strength was documented in 14 during postoperative follow-up.

Dural injury occurred in three patients (3.85%) and was recognized intraoperatively in all cases. No postoperative cerebrospinal fluid leakage or pseudomeningocele was observed, and none of these patients required reoperation for the dural injury. Postoperative headache occurred in three patients (3.85%) and resolved with conservative management. In addition, one patient with a history of anticoagulant use developed worsening leg pain during the sixth postoperative hour. Subsequent postoperative lumbar magnetic resonance imaging revealed an epidural hematoma (n=1, 1.28%), and the patient subsequently underwent urgent open surgical evacuation. Following the second operation, the patient was discharged without any neurological deficit. Other postoperative complications are summarized in Table 1.

Table 1. Demographic, clinical, and postoperative characteristics of patients undergoing unilateral biportal endoscopic lumbar surgery (n=78)

Variable	Groups	Number of patients, n (%)
Gender	Female	42 (53.85%)
	Male	36 (46.15%)
Pathology	Lumbar disc herniation	56 (71.79%)
	Lumbar spinal stenosis	22 (28.21%)
Surgical level	L2-3	3 (3.85%)
	L3-4	7 (8.97%)
	L4-5	30 (38.46%)
	L5-S1	38 (48.72%)
Postoperative complications	Dural injury	3 (3.85%)
	Epidural hematoma	1 (1.28%)
	Neural injury	0 (0%)
	Recurrence	2 (2.56%)
	Headache	3 (3.85%)
	Visual loss	1 (1.28%)
	Infection	0 (0%)
	Cerebrospinal fluid fistula	0 (0%)

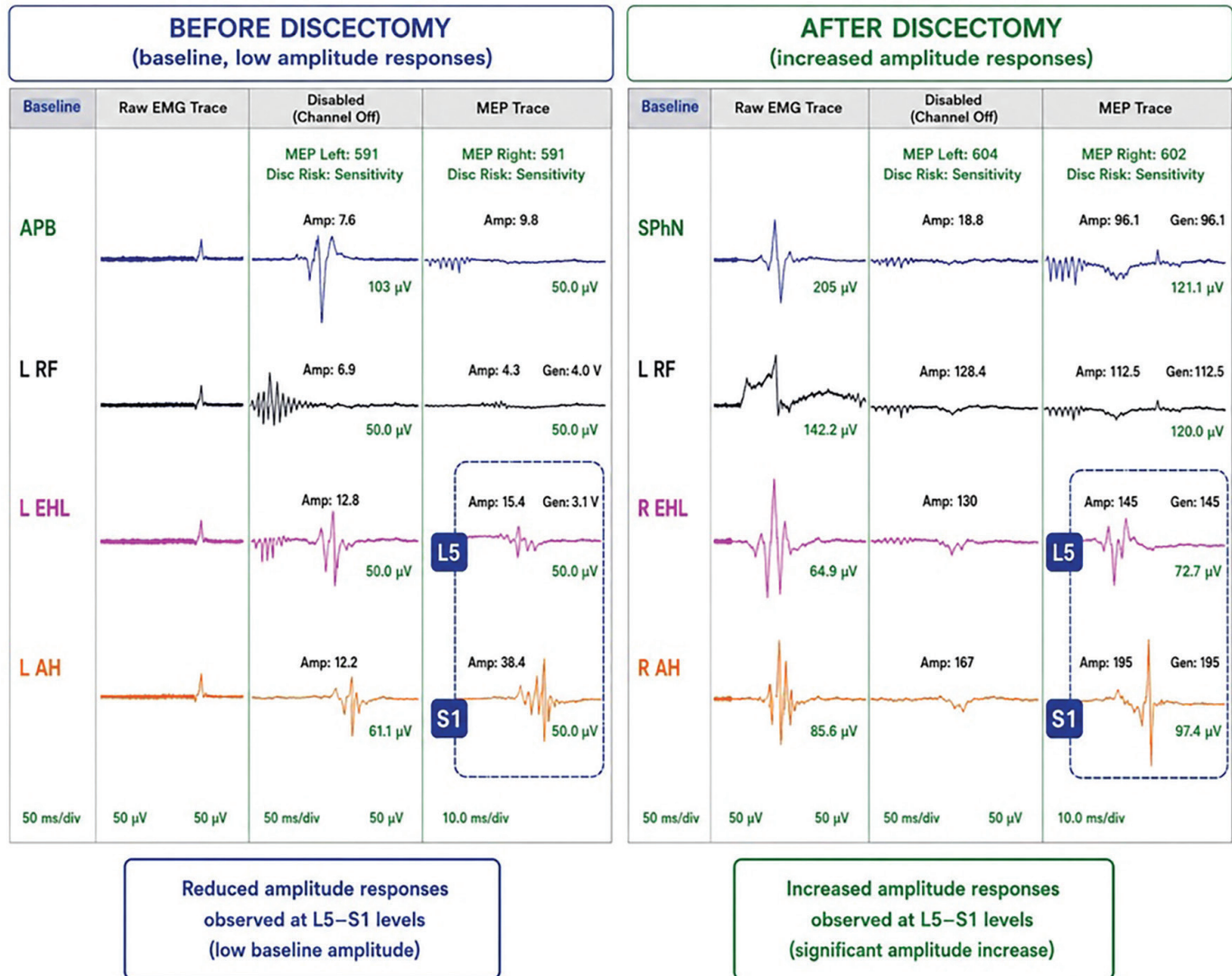


Figure 1. Representative motor evoked potential (MEP) recordings obtained from a patient with L5-S1 lumbar disc herniation before and after discectomy. Baseline recordings demonstrated reduced amplitudes before decompression. Following discectomy, higher MEP amplitudes were observed compared with the baseline recording. EMG: Electromyography, SPhN: Sphincter electromyography channel, APB: Abductor pollicis brevis, RF: Rectus femoris, EHL: Extensor hallucis longus, AH: Abductor hallucis

DISCUSSION

This retrospective study evaluated multimodal IONM, including freeEMG, MEP, and SEP, during lumbar discectomy and decompression using UBE, with a particular focus on intraoperative electrophysiological observations and their relationship to surgical maneuvers. The principal findings of the present study were as follows: (1) freeEMG activity temporally associated with electrocautery use was observed in 41.0% of patients, (2) the freeEMG activity returned to baseline after reduction of the electrocautery power setting, and (3) no new postoperative neurological deficits were identified (0/78). Surgery with UBE requires operative manipulation in close proximity to neural structures, while the limitations of the

endoscopic working corridor and visualization may restrict direct recognition of neural irritation or injury. For this reason, real-time neural monitoring has been considered conceptually valuable during these procedures^(7,9,10,12). Previous studies investigating the use of IONM in surgery with UBE have demonstrated that intraoperative freeEMG changes may provide early warning of neural irritation, allowing timely corrective interventions that may contribute to preservation of neurological function and favorable early postoperative outcomes^(3,5,9,13). Our observations are consistent with the use of freeEMG as an event-related monitoring modality during surgical manipulation. In the present study, freeEMG events were identified qualitatively based on repetitive or sustained electrophysiological activity and its temporal relationship to electrocautery use or the ongoing

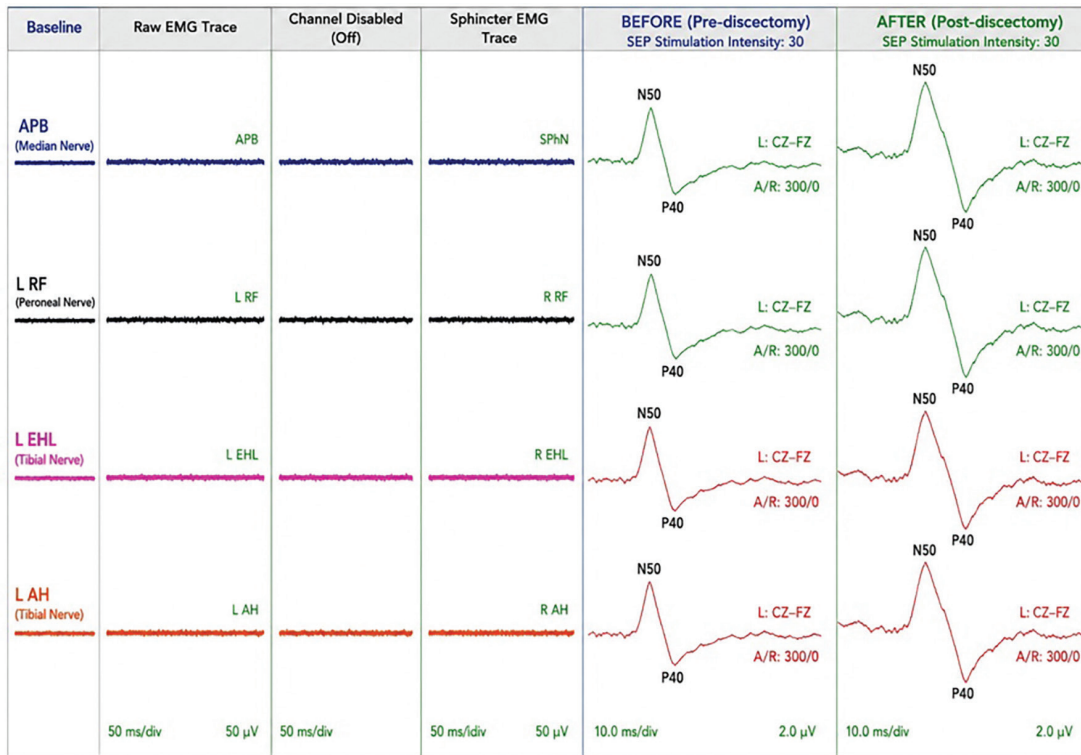


Figure 2. Representative somatosensory evoked potential (SEP) recordings obtained before and after discectomy in a patient with right L5-S1 lumbar disc herniation. Post-discectomy recordings demonstrated higher SEP amplitudes compared with baseline values. EMG: Electromyography, APB: Abductor pollicis brevis, RF: Rectus femoris, EHL: Extensor hallucis longus, AH: Abductor hallucis, CZ-FZ: Central-frontal electrode montage, A/R: Accepted/rejected sweeps

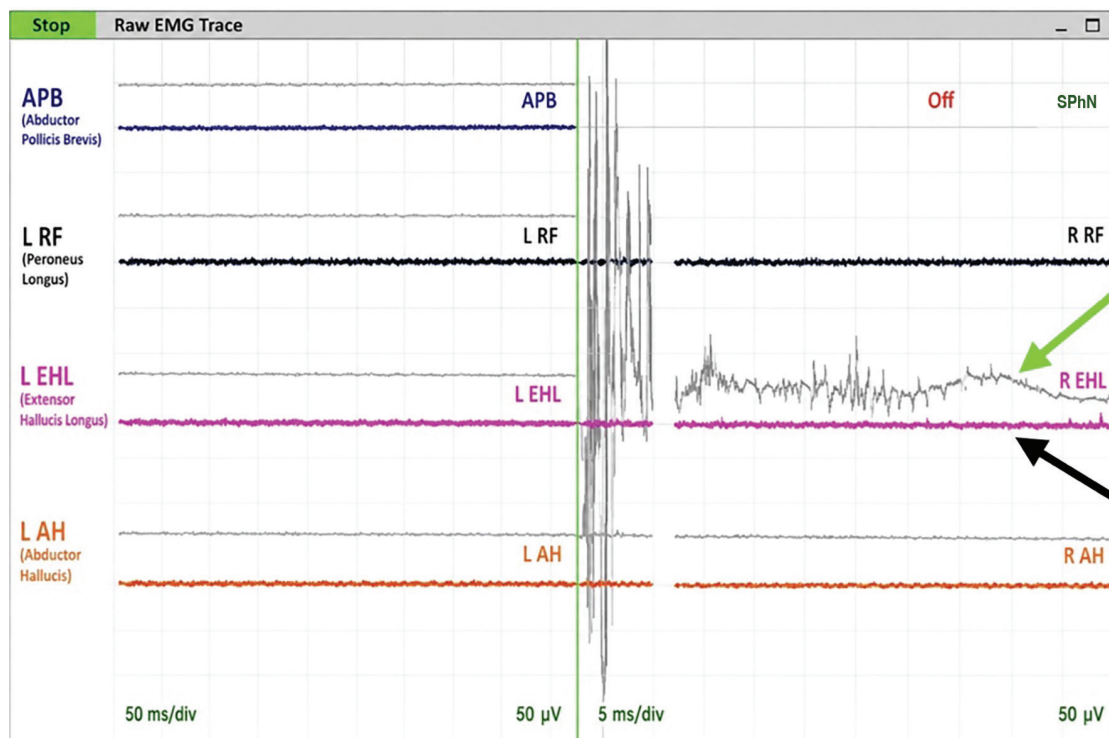


Figure 3. Intraoperative free-running electromyography (freeEMG) recording demonstrating electrophysiological activity observed during electrocautery use (green arrow). Following reduction of the electrocautery setting, the electrophysiological activity returned to baseline (black arrow). APB: Abductor pollicis brevis, RF: Rectus femoris, EHL: Extensor hallucis longus, AH: Abductor hallucis, SPhN: Sphincter electromyography channel

surgical maneuver. These findings prompted intraoperative reassessment and adjustment of the electrocautery settings. Similar observations regarding the use of intraoperative electrophysiological feedback have been reported previously^(9,13-15). However, because the observed activity occurred during electrocautery use, electrocautery-related interference could not be reliably excluded retrospectively. Therefore, the normalization of freeEMG activity after reducing the electrocautery setting cannot be attributed exclusively to resolution of neural irritation. These observations should be interpreted as freeEMG activity temporally associated with electrocautery use rather than evidence of confirmed nerve root injury. Future prospective studies using standardized electrophysiological criteria may help distinguish neurotonic activity from procedure-related artifacts.

Endoscopic spinal surgery is associated with a substantial learning curve, particularly when operating near neural and vascular structures. In surgery with UBE, risk-adjusted learning curve models incorporating neuromonitoring feedback have been proposed to facilitate safer acquisition of technical proficiency by enabling early recognition and correction of potentially hazardous maneuvers through neural irritation alerts^(1,4,16). Although the present study was not specifically designed to evaluate the learning curve, the relatively high frequency of freeEMG activity observed during electrocautery use (41.0%) and the subsequent intraoperative responses illustrate the potential role of real-time electrophysiological feedback during technically demanding endoscopic procedures. Previous learning curve analyses in biportal endoscopic spine surgery have shown that increasing surgical experience affects not only operative duration but also overall procedural safety^(1,16). These observations further support the concept that real-time neural feedback obtained through IONM may provide additional information during surgical technique development and intraoperative decision-making^(7,8).

Several reports in the literature have emphasized the importance of neuromonitoring in endoscopic procedures performed through narrow operative corridors, particularly in anatomically challenging regions where neural structures remain vulnerable during surgical access and decompression^(4,6,13,17). In such procedures, routine monitoring that merely provides retrospective warning signals may be insufficient, whereas immediate intraoperative feedback may have greater clinical relevance^(6,13,15,18). Technical innovations in endoscopic decompression combined with EMG-based neuromonitoring have also been suggested to provide real-time guidance for neural localization and instrument manipulation, potentially reducing the risk of nerve irritation during surgery^(6-8,13).

In studies involving transforaminal endoscopic spine surgery, multimodal neuromonitoring has additionally been reported to assist not only in detecting neural irritation but also in identifying incomplete decompression intraoperatively^(4,6,13). Although the present study focused on the interlaminar approach with UBE,

the fundamental safety rationale remains similar: minimizing delayed or retrospective recognition of neural compromise through proactive intraoperative adjustment and prevention of neural injury.

Study Limitations

No new postoperative neurological deficits were observed in this series; however, in the absence of a control group, this finding cannot be attributed to the use of multimodal IONM. An important limitation of the present study is the absence of validated patient-reported outcome measures, such as the visual analog scale and Oswestry disability index. Consequently, postoperative pain relief, functional recovery, and the overall clinical outcome of the procedure could not be evaluated using standardized outcome measures despite the available follow-up. In addition, because this study was designed as a retrospective descriptive case series, no analytical comparisons were performed between IONM findings and operative or clinical variables. Predefined quantitative electrophysiological alarm thresholds were not prospectively established, which may limit the reproducibility of the IONM findings across different clinical settings. Consequently, the present findings should be interpreted as descriptive observations rather than evidence of clinical effectiveness or prognostic association. Future prospective studies incorporating comparative statistical analyses, standardized outcome measures, and quantitative electrophysiological assessments are needed to further evaluate the clinical value of multimodal IONM. No formal statistical comparison of preoperative and postoperative neurological status was performed because of the limited number of patients with preoperative motor weakness. Another limitation is that quantitative electrophysiological data, including amplitude and latency measurements of MEP and SEP, were not systematically recorded for retrospective analysis. Consequently, the present study was limited to qualitative interpretation of IONM findings, and future prospective studies incorporating standardized quantitative electrophysiological parameters may provide a more objective assessment of intraoperative neural function.

CONCLUSION

In unilateral biportal endoscopic lumbar discectomy and decompression, multimodal IONM using freeEMG, MEP, and SEP provided real-time electrophysiological information throughout the procedure. FreeEMG activity was observed in temporal association with electrocautery use and returned to baseline after modification of the electrocautery settings. However, because this study was retrospective and did not include a control group, these observations cannot establish a protective effect of IONM or its influence on neurological outcomes. Prospective controlled studies are needed to further evaluate its clinical value.

Ethics

Ethics Committee Approval: The study was approved by the Hitit University Local Ethics Committee (approval no: 2025-124, date: 03.06.2025).

Informed Consent: Owing to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.D., Concept: A.D., D.E., Design: G.K., Data Collection or Processing: A.D., Analysis or Interpretation: G.K., Literature Search: G.K., D.E., Writing: A.D., D.E.

Conflict of Interest: No conflict of interest was declared by the authors.

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