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# Assessing the Usefulness of Motor-Evoked Potential Changes in Disc Height Determination in Patients with Degenerative Disc Diseases Treated with Interbody Fusion

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## ABSTRACT

**AIM:** To evaluate the effectiveness of improved motor-evoked potentials (MEPs) in treatment of degenerative disc diseases using the transforaminal lumbar interbody fusion (TLIF) technique.

**MATERIAL and METHODS:** Data of one hundred and eleven patients who underwent TLIF were retrospectively reviewed. The inclusion criteria were preoperative radiculopathy and presence of neurological deterioration without previous surgery. Improved MEP amplitudes reaching the baseline MEP amplitudes of the contralateral side at the same level were used as the thresholds for determining the final disc height and cage size during surgery. Cage size, disc heights of the three areas, foraminal area, and global spinal and local balance were measured.

**RESULTS:** Twenty-two patients (3 male and 19 female) with a mean age of 61.9 ± 8.9 years were included into the study. The mean height of cages was 10.3 ± 1.4 mm (range, 8–14 mm). The mean improvement in MEP amplitude was 27 ± 11% (range, 15–50%). The anterior, middle, and posterior disc heights improved to 2 ± 1.6, 2.7 ± 1.7, and 1.7 ± 1.3 mm, respectively. The improvement in the middle disc height was significantly greater (p<0.05). Segmental lordosis improved from 16.2° ± 10.7° to 19.4° ± 9.2°. Additionally, lumbar lordosis improved from 46.7° ± 14.6° to 51.2° ± 11.2° (p < 0.05). Cage height or improvements in disc height was not correlated with MEP changes. However, there was a positive correlation between ipsilateral foraminal area restoration and MEP changes (r=0.501; p<0.01).

**CONCLUSION:** Improved MEP amplitudes reaching the baseline MEP amplitudes of the contralateral side of the same spinal level might be a useful threshold for determining the final minimum disc height during TLIF surgery with satisfactory postoperative radiological results, including sagittal and segmental radiological parameters.

**KEYWORDS:** Transforaminal lumbar interbody fusion, Lumbar vertebrae, Spinal foramen, Intraoperative neurophysiological monitoring, Motor-evoked potentials

## INTRODUCTION

The main aim of lumbar surgery for degenerative disc disease is to provide normal spinal anatomy, including components of the neural foramen and sagittal balance, with decompression of the neural structure (6,8,14). Some authors have indicated that posterolateral fusion was sufficient to achieve solid bone fusion. It is well known that interbody fusion has a better fusion rate. In addition, interbody fusion has been shown to have high success rates in restoring spinal malalignment and foraminal enlargement (4,6).

The most popular interbody fusion technique is transforaminal interbody fusion (TLIF), which protects the posterior bony structure and provides direct foraminal decompression. Increase in the intervertebral disc height, foraminal height (FH), and foraminal area (FA) leads to not only neural decompression but also restoration of the lumbar lordosis angle (LLA)

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(3,12,13,15). It is not always possible to determine the optimal disc height using preoperative measurements or even achieve preoperative plans. In the literature, there is no correlation with reaching the optimal disc height after TLIF.

Intraoperative neurophysiological monitoring (IONM) has been widely used for spinal procedures to ensure safety (5,7,9,20,26). Many studies have shown that somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs) were useful tools for determining nerve root pathology (9). Initially, IONM was used for identifying spinal injury against radicular injury (5,7,9,20,26). Some animal studies have focused on SEPs and MEPs, showing that these tools were useful for determining positive effects on nerve root recovery after decompression (2,11,19,24). Recently, large series studies have focused on radicular injury and changes in MEPs and reported that MEPs were useful tools for determining radicular nerve injury (18,23). However, there are no reports on the correlation between foraminal height and intraoperative changes in MEPs.

In this study, we aimed to assess the effectiveness of improved MEPs in treatment of degenerative disc disease using the TLIF technique.

## MATERIAL and METHODS

### Patients

A total of 111 patients with degenerative disc disease treated with TLIF surgery at the Istanbul University Istanbul Faculty of Medicine, Department of Orthopedics and Traumatology between 2017 and 2019 were evaluated. The Human Research Ethics approved the study [The Local Ethics Committee of Istanbul University approved this study (2019/658)]. Data were collected from personal records, medical files, and radiological images. All patients underwent surgery by a single orthopedic spine surgeon, and each surgical procedure was performed using the same technique. The inclusion criteria were: (i) preoperative radiculopathy or presence of neurological deterioration and (ii) radiologically proven disc height collapse compared with the adjacent segment. The exclusion criteria were: (i) revision of previous fusion surgery; (ii) surgery at three or more levels to obtain sagittal imbalance; (iii) insufficient imaging data; and (iv) central stenosis treated with wide laminectomy. Twenty-two patients were enrolled in this study (Figure 1). Data of age, sex, diagnosis, fusion level, and cage height were also collected.

### Anesthetic Management

Regarding IONM evaluation, fentanyl (2–3 mcg/kg) for narcotic analgesia, propofol (3 mg/kg) for hypnotic anesthesia, and rocuronium (0.6 mg/kg) for short-term muscle relaxation were administered to facilitate intubation and induction. Anesthesia was maintained with fentanyl (0.05–0.2 mcg/kg/min) and propofol (75–300 Âµg/kg/h) infusion.

### Surgical Technique

The surgical procedure was performed with patients in the prone position under general anesthesia. The baseline MEP amplitudes were recorded before incision. A midline skin incision was made over the lumbar segment. The skin, muscles, and soft tissues were gently retracted to expose the posterior elements. The surgical level was confirmed using fluoroscopy. A facetectomy was performed, and transpedicular screws were placed bilaterally. MEP amplitudes were recorded before and after foraminotomy, discectomy, and decompression. The disc space was expanded using a distractor. The annulus was penetrated using a scalpel. Discectomy was performed using a curette and a punch. The vertebra end plates were prepared. Additionally, gradual distractions were continued until the trial cage tightly fitted. After distraction, the cage was increased

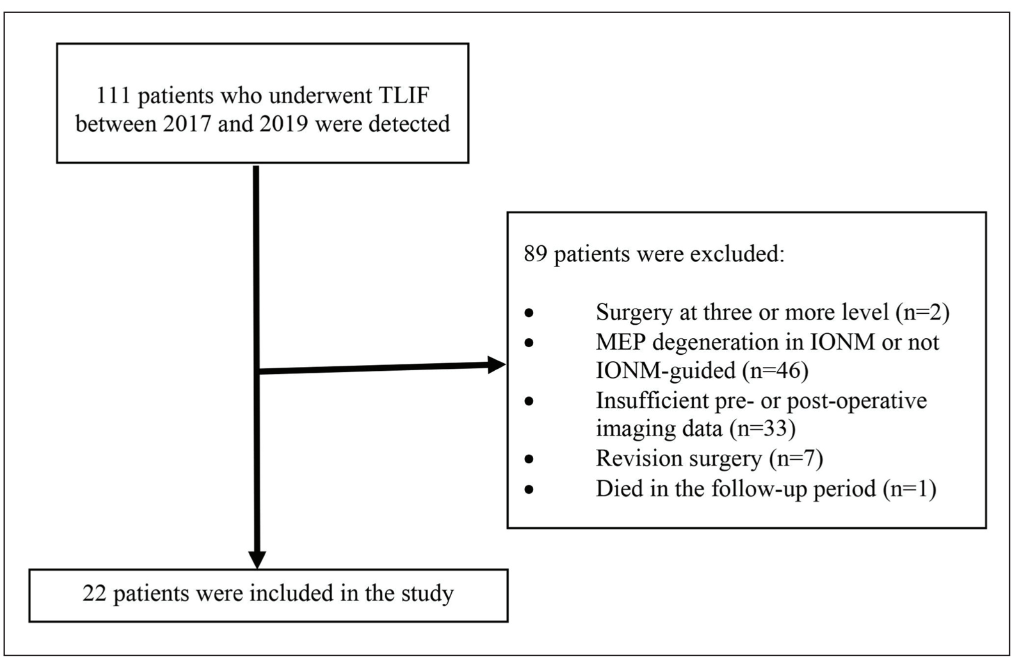


**Figure 1:** Flow chart of the patient inclusion. **TLIF:** transforaminal lomber interbody fusion, **IONM:** intraoperative neurophysiological monitoring, **AP:** antero-posterior; **CT:** computerized tomography, **MR:** magnetic resonance.

starting with 7 mm at 1-mm intervals. When tightness was reached, the MEP amplitude was re-recorded. When the improved MEP amplitude reached the baseline MEP amplitude of the contralateral side at the same level, the final disc height was determined and the appropriate cage height was chosen (Figure 2). The graft-filled titanium cage was placed as far as possible through the transforaminal route to the anterior and midline of the intervertebral space. This was confirmed by lordosis measurement compared with side radiography performed preoperatively. If cage was appropriately placed, the rods were compressed and locked from both sides. The MEP amplitudes were recorded after the rods were locked.

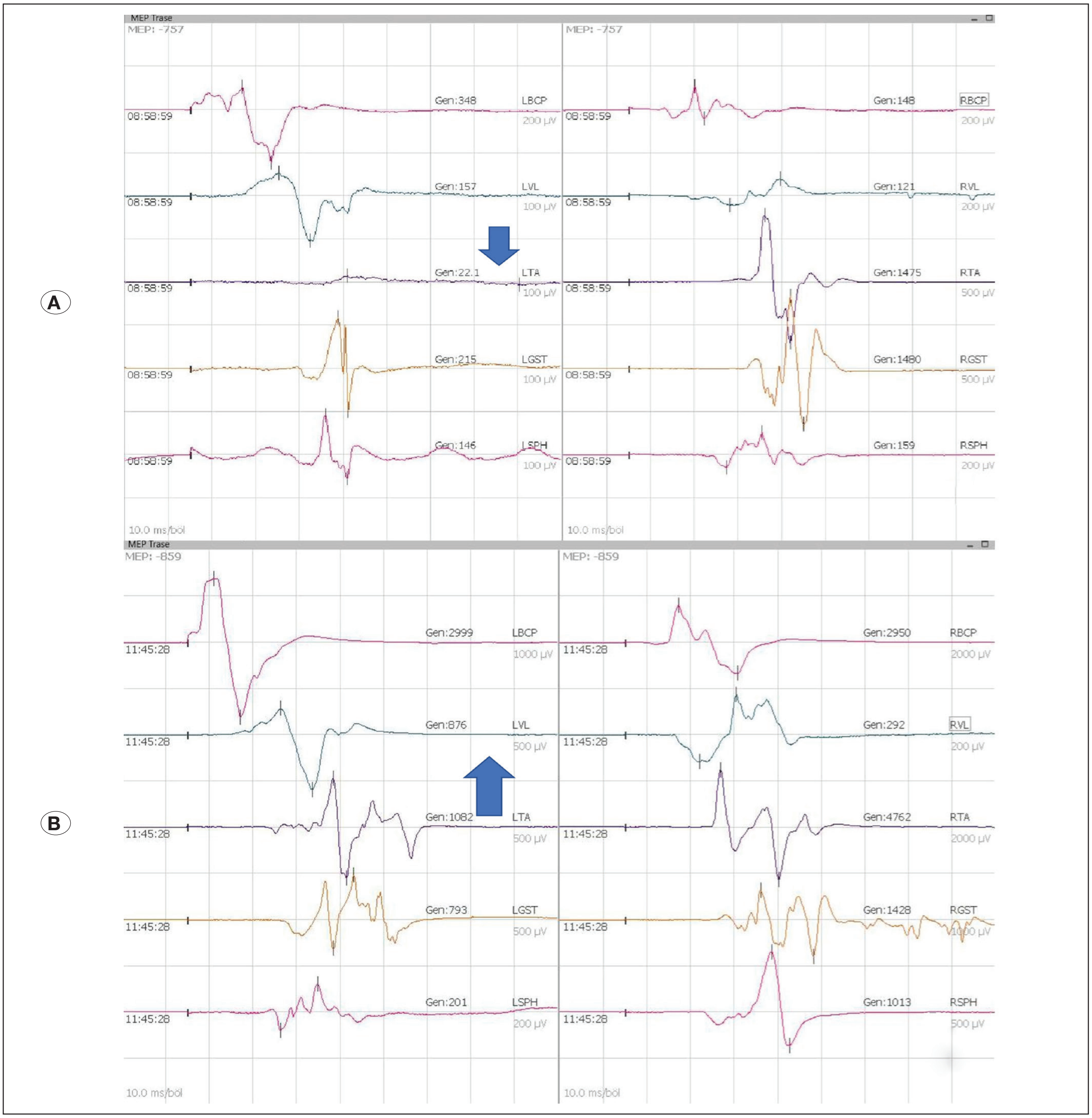


**Figure 2: A)** The low MEP amplitude (blue arrow) before the surgery is seen on the left tibialis anterior. **B)** Improvement in the MEP amplitude (blue arrow, left tibialis anterior) reaching the baseline MEP amplitude of the contralateral side (right tibialis anterior) after cage placement is seen. **MEP:** motor evoked potential.

The contralateral side was decorticated for the grafting bed, and a spongious allograft was applied for fusion. The wound was closed in layers over the suction drain.

### IONM Technique

Transcranial electrical stimulation was delivered through the corkscrew electrodes that were placed approximately 7 cm above both ears (standard C1 and C2 positions of the 10–20 EEG system) toward the midline of the skull. Subdermal needle electrodes were placed in the muscles with MEP activity: the rectus femoris, tibialis anterior, extensor hallucis longus, and medial gastrocnemius stimulated by transcranial stimulation. The NIM Eclipse® device (Medtronic, Medtronic Inc., Jacksonville, FL, USA) was used for IONM. MEP amplitudes were recorded every 1 mm distraction with a cage trial starting from 7 mm. To eliminate the negative effects of anesthetic procedures, change in the amplitude of the upper extremity and adjacent myotome was determined and calculated. The amplitude change was calculated as a percentage. The cutoff point of the enhanced cage height was increased, of which the MEP value was equal to that of the contralateral side.

### Radiological Assessment

Pre- and post-operative computed tomography (CT) scans and full spinal anteroposterior and lateral radiographs were obtained in all patients. Anterior disc height (ADH), middle disc height (MDH), posterior disc height (PDH), ipsilateral and contralateral FH and FA, and global and segmental lordosis with T1 pelvic angle (TPA) were measured using the extreme picture archival and communication system. ADH was defined as a term reflecting the distance between the anterior ends of the inferior and superior endplates. MDH and PDH were defined as the distances between the middle and posterior ends, respectively (Figure 3A) (3). FH was defined as the longest distance between the lower border of the superior pedicle and the upper border of the inferior pedicle (Figure 3B) (3). FA was defined as the area confined by the lower border of the pedicle of the upper vertebra, posterior vertebral line, upper border of the pedicle of the lower vertebra, anterior border of the ligamentum flavum, and anterior border of the inferior articular process of the upper vertebra (Figure 3B) (3).

### Clinical and Functional Assessment

In this study, pain intensity in the patients was assessed using the visual analog scale (VAS). Additionally, the Oswestry Disability Index (ODI) score was used to assess functional outcomes pre-operatively and at the latest follow-up visit.

### Statistical Analysis

The Number Cruncher Statistical System 2007 Statistical Software (NCSS LLC, Kaysville, Utah, USA) was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, median, frequency, and rate) were used to analyze the study data. A paired sample t-test was used to analyze dependent variables. Since multiple measurements were obtained in one patient compared with quantitative data, repetitive measurements and different levels of the Generalized Linear Mixed Model analysis were used. Post-hoc evaluations were performed using the Bonferroni corrected test. The results were evaluated in the 95% confidence interval, and the significance level was set at a p-value < 0.05.

## RESULTS

Twenty-two patients, three men (13.6 %) and 19 women (86.3 %), were included in the study. The mean age of the patients was 61.9 ± 8.89 years (range, 37–78 years) at the time of their TLIF operation. The diagnoses included spinal stenosis (n=15), spondylolisthesis (n=5), and adult degenerative scoliosis (n=2). TLIF was performed at a single level in 10 patients and at two levels in 12. A total of 34 cages were used in this study. The mean height of cages was 10.26 ± 1.37 (range, 8–14) mm. The mean improvement in MEP amplitudes was 27.27 ± 11.09% (range, 15%–50%) on the operative side. None of the patients had decreased MEP amplitudes during surgery. Table I summarizes patient characteristics. No statistically significant correlation was found between MEP changes and cage heights.

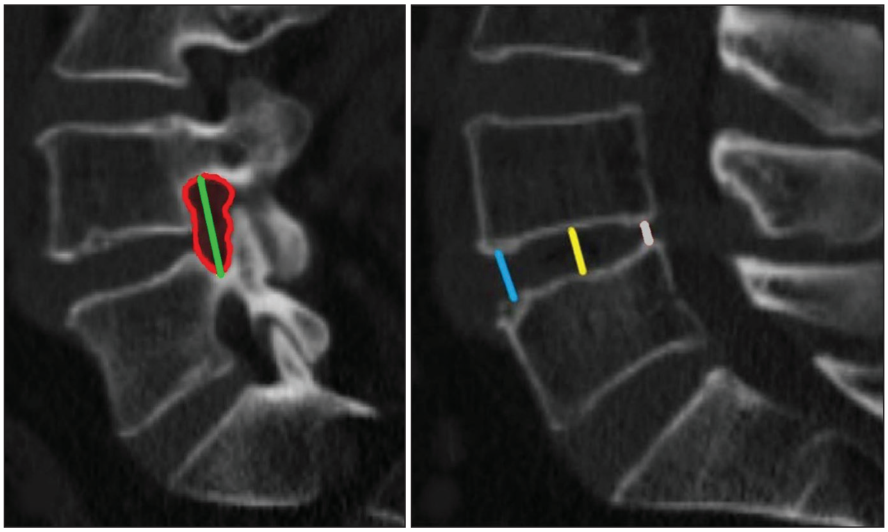

**Figure 3:** Measurements of spinal morphometric parameters from computed tomography scan **A) ADH:** anterior disc height (blue); **MDH:** middle disc height (yellow); **PDH:** posterior disc height (white) **B) FH:** foraminal height (green); **FA:** foraminal area (red).

The restorations calculated between the pre- and postoperative CT scans regarding ADH, MDH, and PDH were 2.02 ± 1.55 mm, 2.73 ± 1.68 mm, and 1.67 ± 1.28 mm, respectively. The increase in MDH was found to be significantly higher than that in ADH and PDH (p=0.023; p<0.05) (Table II). The mean value of the increase in PDH was the lowest among the three disc heights. The restorations of the ipsilateral and contralateral FH were calculated: 2.01 ± 1.09 mm and 1.83 ± 1.39 mm, respectively. According to the postoperative CT scans, ipsilateral and contralateral FAs were found to be enlarged at 64.47 ± 68.11 mm$^2$ and 41.67 ± 45.33 mm$^2$, respectively (Table II). There was a positive correlation between MEP improvement and ipsilateral FA enlargement (r = 0.501; P 0.01) (Figure 4).

Segmental lordosis improved from 16.2° ± 10.7° to 19.4° ± 9.2° and LL improved from 46.7° ± 14.6° to 51.2° ± 11.2° (p<0.05). TPA was improved from 9.96° ± 10.7° to 11.2° ± 10.2°.

The average preoperative VAS score was 8.27 ± 2 (range, 4–10) and improved to 2.1 (range 0–-4) at the latest follow-up (p<0.001). The mean pre-operative ODI score was 38.4 (range, 28–44) and improved to 13.4 (range, 11–16) at the latest follow-up (p<0.001).

## DISCUSSION

IONM has been widely used for identifying and preventing neural injuries during spinal surgeries in recent years (5,7,12). MEPs have been widely accepted to be reliable for detecting postoperative deficits. However, their extreme sensitivity to inhaled volatile gases necessitates the use of intravenous anesthetic agents in practice (9,26). Several studies have reported that MEP monitoring was an effective tool for detecting nerve root injuries during spinal deformity correction (18,23,25). However, little is known about the possible positive effects of surgical decompression surgery on electrophysiological responses (10,16,17,22,25). Some studies have eval-

**Table I:** Summarized Characteristics of the Patients (MEP, Motor Evoked Potential)

| | |
|---|---|
| Patients (n) | 22 |
| Male | 3 (13.6%) |
| Female | 19 (86.3%) |
| Mean age at the time of the surgery (years) | 61.9 ± 8.9 (range, 37-78) |
| Spinal levels (n) | |
| Single level | 10 |
| Two levels | 12 |
| L2-L3 | 1 |
| L3-L4 | 7 |
| L4-L5 | 19 |
| L5-S1 | 7 |
| Mean height of the cages (mm) | 10.3 ± 1.4 (range, 8-14) |
| Mean MEP improvement (%) | 27 ± 11 (range, 15-50) |

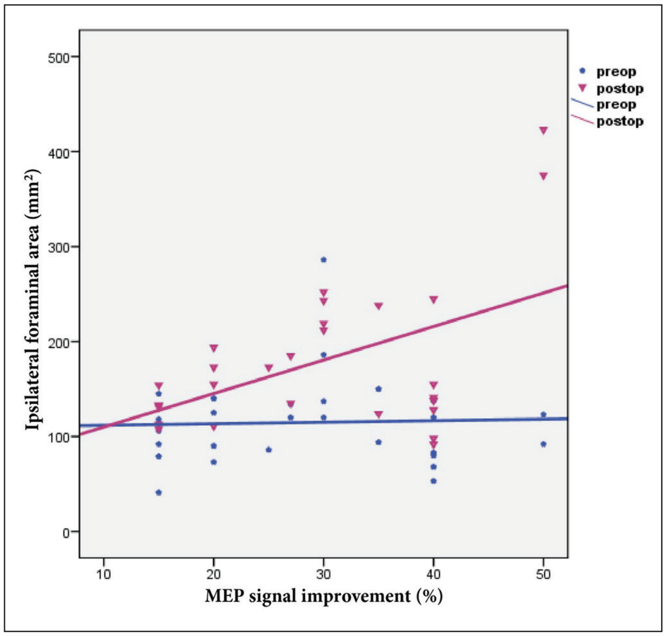


**Figure 4:** The correlation between MEP improvement and ipsilateral foraminal area enlargement. **MEP:** motor evoked potential.

**Table II:** The Changes in the Spinal Morphometric Parameters

| | Pre-operative measurement | Post-operative measurement | Restoration |
|---|---|---|---|
| ADH | 9.42 ± 3.17 mm | 11.44 ± 2.61 mm | 2.02 ± 1.55 mm |
| MDH | 7.23 ± 2.62 mm | 9.96 ± 1.95 mm | 2.73 ± 1.6 mm |
| PDH | 3.50 ± 1.53 mm | 5.18 ± 1.93 mm | 1.67 ± 1.28 mm |
| IFH | 16.35 ± 4.25 mm | 18.36 ± 4.03 mm | 2.01 ± 1.09 mm |
| IFA | 114.08 ± 44.60 mm$^2$ | 178.55 ± 72.63 mm$^2$ | 64.47 ± 68.11 mm$^2$ |
| CFH | 16.88 ± 3.80 mm | 18.72 ± 3.37 mm | 1.83 ± 1.39 mm |
| CFA | 120.55 ± 39.81 mm$^2$ | 162.23 ± 50.59 mm$^2$ | 41.67 ± 45.33 mm$^2$ |

***ADH:** Anterior disc height, **MDH:** Middle disc height, **PDH:** Posterior disc height, **IFH:** Ipsilateral foraminal height, **IFA:** Ipsilateral foraminal area, **CFH:** Contralateral foraminal height, **CFA:** Contralateral foraminal area.*

uated the correlation between MEP improvement and functional outcomes and found promising results (16,17,22). Wang et al. assessed the effectiveness of MEP improvement in the functional outcomes in patients undergoing cervical decompression surgery (21). Patients who had improved MEPs after decompression of the cervical cord had a better prognosis in early and long-term neurological function recovery (22). This study showed that monitoring intraoperative MEPs could prevent neural injury and assess neural recovery (22).

Inadequate clinical human studies have focused on spinal nerve or peripheral nerve neuromonitoring. Some animal studies have shown that MEP value improvement was better correlated with nerve function monitoring (2,11,19,24). Bayram et al. showed that MEP value was a useful tool for determining sciatic nerve injury (1). In addition, there was insufficient data on renervation. Animal studies presented separately by Jou et al. and Brauckhoff et al. showed the compression time and effect of renervation on the spinal nerve under neuromonitoring (2,11). MEP value improvements were calculated as percentages because MEP amplitudes could show differences depending on patient (1,2,24). Thus, in the current study, we also calculated MEP amplitude improvements as percentages to eliminate differences between the participants. In the literature, there is agreement that perioperative MEPs values have good correlation with clinical findings (18,23). However, the literature lacks knowledge of MEP improvement in the functional outcomes in patients with lumbar radicular problems. Our study showed that MEPs were useful tools for determining nerve root decompression.

Interbody fusion has been reported to be important for achieving solid fusion and balanced sagittal misalignment. It could be performed either anteriorly or posteriorly. In daily practice, we perform posterior transforaminal interbody fusion to protect patient from morbidity following anterior surgery. Determining interbody cage height is important due to its influence on segmental and sagittal lordosis. To date, there is no consensus on the ideal disc and cage heights for interbody fusion (3,12,13,15). There are no data published in the literature regarding the effect of neurophysiological examinations on the determination of disc height. In this study, we attempted to determine any correlation between cage height and MEPs value improvement. The cage height threshold was calculated by reaching the MEPs values to the contralateral side. We found that using improved MEP amplitudes to determine the final minimum disc height provided desirable results in patients undergoing TLIF with satisfactory postoperative radiological results, including sagittal and segmental radiological parameters.

Morphometric changes, including ADH, MDH, PDH, ipsilateral FH, contralateral FH, and FA were all found to be increased postoperatively without correlation with MEP improvement. The mean increase in PDH was the lowest among the three morphometric parameters. We suggest that this difference in increases in the three different disc heights supported the restoration of LLA. Statistical analysis showed no correlation between MEP improvement and cage height. However, improved MEP amplitudes may reflect decompression of the nerve root in line with the restoration of FA due to the statistically significant correlation between FA and MEP amplitude improvement ($r = 0.501$; $p<0.01$).

The main limitation of the current study was its small sample size. However, to our best knowledge, this is the first study to evaluate the correlation between morphometric changes after TLIF surgery and MEP changes in terms of improvement in clinical results.

## CONCLUSION

Improvements in MEP amplitude were significantly correlated with contralateral decompression of the nerve root. Moreover, improved MEP amplitudes reaching the baseline MEP amplitudes of the contralateral side of the same spinal level seem to be a useful threshold for determining the final minimum disc height in patients undergoing TLIF surgery with satisfactory postoperative radiological results, including sagittal and segmental radiological parameters.

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**AUTHORSHIP CONTRIBUTION**

Study conception and design: YS, TA
Data collection: YS
Analysis and interpretation of results: YS, SB
Draft manuscript preparation: YS, SB, TA
Critical revision of the article: TA, SB
All authors (YS, SB, TA) reviewed the results and approved the final version of the manuscript.

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