

# New Intramuscular Electromyographic Monitoring with a Probe in Lateral Lumbar Interbody Fusion Surgery

Shigeto Ebata, Tetsuro Ohba and Hirotaka Haro

*Department of Orthopaedic Surgery, Graduate School of Medicine, University of Yamanashi, Yamanashi, Japan*

## Abstract:

**Introduction:** The lateral lumbar interbody fusion (LLIF) surgical approach is minimally invasive and safely accesses the target region. Therefore, it is widely used in cases of lumbar spinal stenosis and spinal deformity. Intraoperative neuromonitoring is necessary to avoid nerve injury, whereas postoperative anterior thigh symptoms are not necessarily prevented.

**Technical Note:** In our institute, 85 LLIF operations have been performed. The first 30 cases were excluded from the present study to avoid surgical learning curve effects; conventional monitoring was used in 30 cases, whereas a new method with a probe to monitor intramuscular potential was used in 25 other cases. Anterior thigh symptoms and motor deficits were assessed postoperatively. The location of the electromyographic threshold decrease was at the posterior part of the disc at L2-3, but at the anterior part at L4-5. Compared with conventional monitoring, the new intramuscular monitoring significantly decreased the prevalence of motor deficits of the iliopsoas at 1 day and 30 days; anterior thigh pain at 1 day, 30, and 90 days; and anterior thigh numbness at 30 and 90 days postoperatively.

**Conclusions:** Compared with conventional monitoring, the new intramuscular monitoring with a less invasive probe may reduce anterior thigh symptoms.

## Keywords:

Lateral lumbar interbody fusion, Electromyographic monitoring, Intramuscular monitoring, Anterior thigh symptom

Spine Surg Relat Res 2019; 3(1): 106-111

[dx.doi.org/10.22603/ssrr.2018-0079](https://doi.org/10.22603/ssrr.2018-0079)

## Introduction

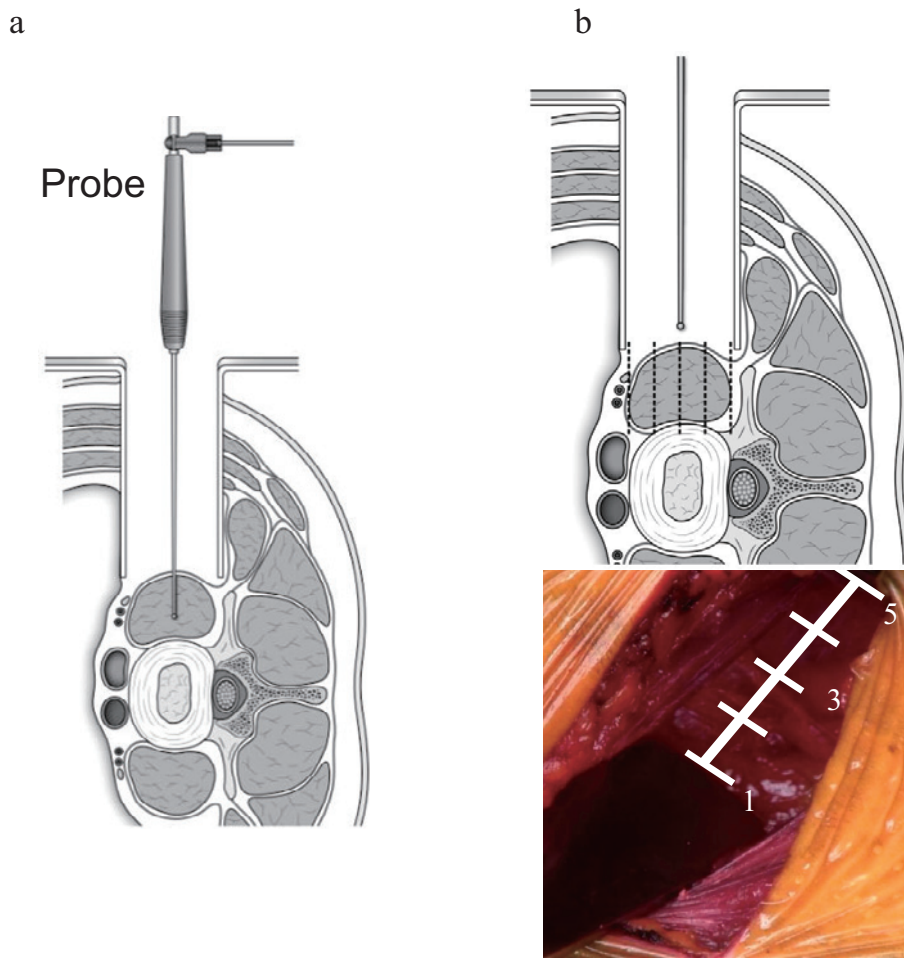
Lateral lumbar interbody fusion (LLIF) provides solid and stable intervertebral fusion, which can correct spondylolisthesis and/or spinal deformities, such as imbalance of sagittal and coronal curvature, and indirect decompression by ligamentotaxis force. The lateral retroperitoneal and transpsoas approaches facilitate quicker access to the target region safely with a small skin incision, minimal bleeding, and direct and wide visualization<sup>1,2)</sup>. Nevertheless, various complications, ranging from slight to severe status related to LLIF, have been reported, such as damage to blood vessels, viscera, and nerves<sup>3-6)</sup>. Among them, anterior thigh symptoms, including muscle weakness of quadriceps or abductors, and anterior thigh pain and hypesthesia have been commonly experienced postoperatively<sup>7,8)</sup>. Additional intraoperative-neurophysiological monitoring methods have been widely used, and are necessary to identify the distribution of the lumbar nerve plexus near the intervertebral disc

and prevent nerve injury<sup>9,10)</sup>. We retrospectively surveyed consecutive surgical cases of lumbar degenerative diseases in the presence or absence of sagittal imbalance and analyzed the relative anatomical position of the lumbar plexus. The distance from the anterior edge of the disc to the lumbar plexus at L2-3, L3-4, or L4-5 or the femoral nerve at L3-4 or L4-5 is significantly less in patients with adult spinal kyphosis, and may be more susceptible to nerve complications<sup>11)</sup>. However, preoperative precise anatomical magnetic resonance imaging (MRI) analysis and intraoperative electromyographic (EMG) monitoring have not prevented anterior thigh symptoms completely<sup>12)</sup>. Therefore, the purpose of the present study was to elucidate the utility of intramuscular potential monitoring compared with conventional surface muscular potential monitoring, and the effects of monitoring with a probe compared with the dilator used conventionally.

Corresponding author: Hirotaka Haro, [haro@yamanashi.ac.jp](mailto:haro@yamanashi.ac.jp)

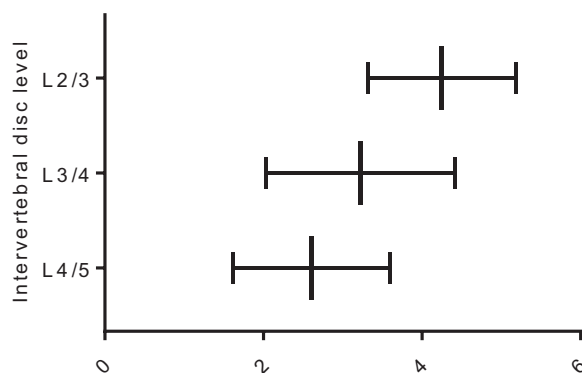
Received: September 18, 2018, Accepted: October 3, 2018, Advance Publication: October 30, 2018

Copyright © 2019 The Japanese Society for Spine Surgery and Related Research



c

The location of the EMG threshold decrease



**Figure 1.** (a) A stimulation clip was attached to the probe and the Neuro Vision electro-myographic (EMG) monitoring system (NuVasive) was activated in detection mode. (b) As the probe was advanced to the psoas muscle, the EMG threshold was detected. EMG thresholds at 5 points at the edges of the anterior and posterior psoas muscles and at 3 boundary points between zones were measured on the surface of the psoas muscles with the probe and as the intramuscular potential in the psoas muscle. The area between the anterior and posterior edges of the psoas muscle was divided into 4 zones, namely, the anterior quarter, middle anterior quarter, posterior middle quarter, and posterior quarter, using the measurement at the level of the intervertebral disc. EMG monitoring was performed with a stimulation clip attached to the probe at 5 points on the surface of the psoas muscle in the conventional manner and at 5 points in the intramuscular layer in a new manner. (c) The EMG threshold decrease was located at the posterior part of the L2-3 disc, but at the anterior part of the L4-5 disc.

## Technical Note

In our institute, LLIF surgeries were performed on 85 patients suffering from lumbar degenerative diseases, excluding a Cobb angle  $>30^\circ$ . Patients included had not responded to nonsurgical treatments with medication and/or orthosis for at least 6 months after first beginning these treatments and were therefore indicated for surgery to treat lumbar spinal stenosis associated with neurological deterioration and to treat adult spinal deformity with a SVA (Sagittal Vertical Axis) of  $> 50$  mm. Patients with previous back surgery, lumbar disc herniation, vertebral fracture, isthmic spondylolisthesis, tumor, or inflammatory diseases were excluded. In this series, LLIF was performed by a single board-certified surgeon according to a surgical procedure described in the literature<sup>9</sup>. The first 30 cases were excluded from the present study to exclude the effect of the surgeon's LLIF-related learning curve. Thirty consecutive cases were monitored intraoperatively using conventional electromyography from March to September 2015<sup>13</sup>; the following 25 consecutive patients were monitored using a newly developed method from October 2015 to July 2016.

The area between the anterior and posterior edges of the psoas muscle was divided into 4 zones, namely, the anterior quarter, middle anterior quarter, posterior middle quarter, and posterior quarter, using a measurement at the level of the intervertebral disc. A stimulation clip was attached to a probe (Fig. 1a) and a Neuro Vision EMG monitoring system (NuVasive) was activated in detection mode. As the probe was advanced into the psoas muscle, the EMG threshold was detected as reported previously<sup>10,14</sup>. The EMG thresholds of the surface potential at 5 points at the edges of the anterior and posterior psoas muscles and at 3 boundary points between zones were measured on the surface of the psoas muscles with the probe (Fig. 1b). As the intramuscular potential, the EMG threshold was also measured at the 5 points after advancing the probe into the psoas muscle. A threshold  $>10$  mA indicates a distance that allows for both continued nerve safety and ample working area. However, an EMG threshold decrease with proximity to the nerve tissues and a threshold of  $\leq 5$  mA indicates possible direct contact with the nerve. A threshold  $>5$  and  $<10$  mA cautions proximity to the nerve<sup>10,14</sup>.

Neurological data regarding motor deficits of the iliopsoas muscle, anterior thigh pain, and anterior thigh sensory disturbance were assessed at 5 time points, namely, on the day immediately after surgery, and at 1 week, at 2 weeks, at 1 month, and at 3 months postoperatively. The neurological function was assessed by evaluating tactile detection and muscle strength using the manual muscle test scale (5 grades of strength). Motor deficits that decreased by  $>1$  level in the manual muscle test were evaluated. Criteria for postoperative anterior thigh pain and numbness were decided on whether patients complained of such symptoms using patient-driven symptom and pain diagrams postoperatively. All assessments were performed by board-certified

**Table 1.** Demographics of Patients.

	Monitoring technique		P
	Conventional (n=30)	New (n=25)	
Age, y	69.1 $\pm$ 10.7	71.24 $\pm$ 8.0	NS
Sex, female/male	23/7	19/6	NS
Number of fused levels	2.5 $\pm$ 0.68	2.9 $\pm$ 1.32	NS
BMI, kg/m <sup>2</sup>	23.8 $\pm$ 4.4	23.4 $\pm$ 4.9	NS
Operative time (min)	311 $\pm$ 156.3	356 $\pm$ 198	NS

BMI: body mass index; NS: not significant

spinal physicians except for a surgeon in charge of cases in a blinded fashion. Data were analyzed using an unpaired t test.

All statistical calculations were conducted using Prism, version 6.0 (Graph Pad Software, La Jolla, CA). For all tests,  $P < 0.05$  was considered significant.

The patients' age at surgery, gender, number of fused levels, body mass index, and operative time are presented in Table 1.

### *Location of the EMG threshold decrease*

The EMG threshold decrease was located in the posterior part of the disc at L2-3, whereas it was anterior of the disc at L4-5 (Fig. 1c). The EMG threshold decrease was located almost in the middle of the disc at L3-4.

### *Motor deficits of the iliopsoas muscle*

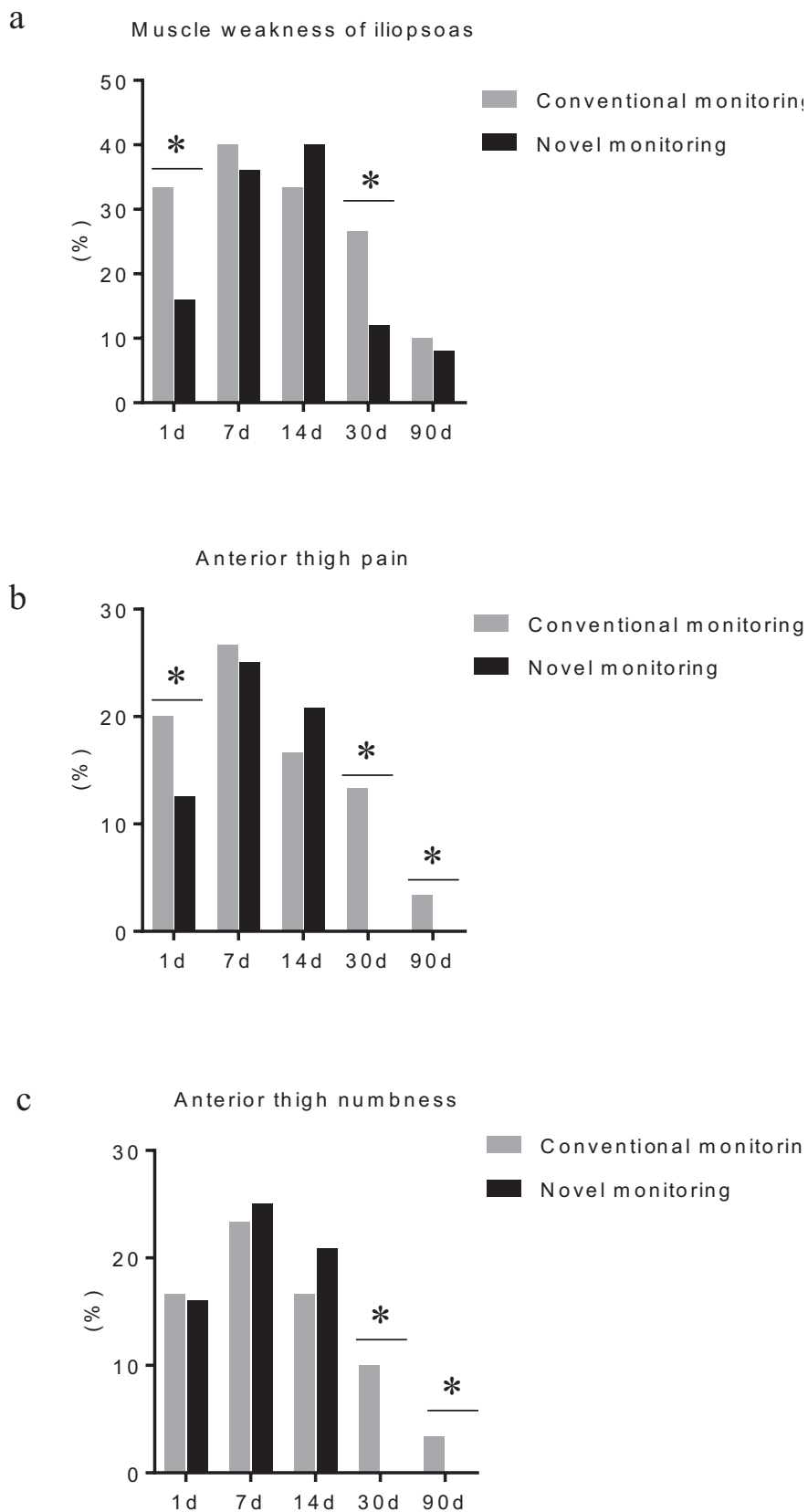
Weakness of the iliopsoas muscle was commonly observed postoperatively. The prevalence of symptoms was increased especially at 7 and 14 days postoperatively, and then decreased at 30 and 90 days postoperatively (Fig. 2a). Compared with conventional monitoring, the new intramuscular monitoring decreased motor deficits of the iliopsoas significantly at 1 day and 30 days postoperatively.

### *Anterior thigh pain*

Anterior thigh pain was commonly observed postoperatively. The prevalence of symptoms was increased especially at 7 and 14 days postoperatively, and decreased at 30 and 90 days postoperatively (Fig. 2b). Compared with conventional monitoring, the new intramuscular monitoring decreased anterior thigh pain significantly at 1 day, 30, and 90 days postoperatively.

### *Anterior thigh numbness*

Anterior thigh numbness was commonly observed postoperatively. The prevalence of symptoms increased, especially from 1 day to 14 days postoperatively, and then decreased at 30 and 90 days postoperatively (Fig. 2c). Compared with conventional monitoring, the new intramuscular monitoring decreased anterior thigh pain significantly at 30 and 90 days postoperatively.



**Figure 2.** (a) Motor deficits of the iliopsoas muscle. (b) Anterior thigh pain. (c) Anterior thigh numbness.

**Discussion**

We developed a new intramuscular monitoring system with a stimulation clip attached to a probe, resulting in the

reduction of anterior thigh symptoms, such as motor deficits of the iliopsoas muscle and anterior thigh pain and numbness.

LLIF surgery includes a procedure to separate the psoas

muscle with a dilator using blunt dissection under the Neuro-Vision JJB EMG monitoring system<sup>10</sup>). The neuromonitoring techniques allow for a precise geographic mapping of the lumbar plexus within the psoas muscle to indicate a safe approach. Adding the current intraoperative EMG approach to the lateral approach to the lumbar spine contributed to a decrease in the rate of complications from 30% to less than 1%<sup>13</sup>). Nerves are at risk during surgery because of the need to dilate or expand muscles using a retractor to approach the discs. A retrospective review of a consecutive series of 71 patients who underwent LLIF performed by a single surgeon found a 19.7% prevalence of ipsilateral thigh numbness with thigh pain and a 54.9% prevalence of motor weakness involving the iliopsoas muscle and/or quadriceps immediately postoperatively<sup>8</sup>). A retrospective review of 235 patients including a total of 444 fused disc levels found the presence of sensory deficits in 28.7% at 6 weeks, 13.1% at 12 weeks, 5.7% at 6 months, and 1.6% at 12 months; a prevalence of anterior thigh pain of 41% at 6 weeks, 16% at 12 weeks, 3.7% at 6 months, and 0.8% at 12 months; and a prevalence of psoas mechanical flexion deficits of 13.1% at 6 weeks, 3.7% at 12 weeks, 2.9% at 6 months, and 1.6% at 12 months<sup>7</sup>). A nationwide survey of 2,998 cases of LLIF (1,995 cases of extreme lateral interbody fusion [XLIF] and 1,003 cases of oblique lateral interbody fusion) in Japan found sensory nerve injuries in 5.1% (5.9% in XLIF) and psoas muscle weakness in 4.3% (4.9% in XLIF). Some 69.1% of patients with sensory nerve injury and 92.8% of patients with psoas muscle weakness showed recovery within 3 months postoperatively<sup>15</sup>). Adverse immediate postoperative neurological impairments, such as anterior thigh symptoms and motor weakness of the psoas and quadriceps, are difficult to avoid even if intraoperative neuromonitoring systems are used, and cause distress to patients and surgeons<sup>12</sup>).

A prospective clinical study from 9 US centers, including 102 consecutive patients undergoing XLIF at L3-4 and/or L4-5, investigated the effectiveness of dynamic EMG monitoring to detect nerves and prevent neural injury<sup>14</sup>). The EMG thresholds for each of 3 successive dilators were recorded at the surface of the psoas muscle, mid-psoas, and at the spine. At each location, the dilators were rotated 360°, while recording immediately posterior, superior, and inferior to its location. Nerves were identified near the dilators in 55.7% of cases. Postoperative upper medial thigh sensory loss was found in 27.5% of cases, iliopsoas/hip flexion weakness in 17.6%, and motor neural deficits of foot-dorsiflexion or quadriceps/knee extension weakness in 2.9%.

Current intramuscular monitoring demonstrated that the EMG threshold was located in the posterior part of the disc at L2-3, but in the anterior part of the disc at L4-5. This finding is consistent with our previous MRI study<sup>11</sup>) and MRI tractography<sup>16</sup>). The nerve plexus was located in the dorsal part of the disc at L4-5, but in the anterior part of the disc at L2-3.

The present study demonstrated that the prevalence of

postoperative adverse effects, including muscle weakness of the iliopsoas, anterior thigh pain, and anterior thigh numbness, using conventional monitoring systems was almost the same as or less than those reported previously<sup>8</sup>). The new intramuscular neuromonitoring system allowed a more precise detection of nerves than conventional muscle surface monitoring. In addition, the new system used a probe whose tip was much smaller in diameter than the conventionally used dilator, allowing the new system to be much less invasive and therefore safer than the conventional system. The new system resulted in a significant reduction in the prevalence of 3 adverse effects immediately postoperatively. By contrast, none of the 3 adverse effects showed any significant differences between the new and conventional monitoring systems at 7 and 14 days postoperatively, so the new system was not able to decrease the effects at these times. There may be some other reason for these effects at 7 and 14 days after surgery. The reason for anterior thigh symptoms may be both direct muscular damage, resulting in hematoma around the surgical entry region, and direct nerve damage. Acute muscular damage with hematoma might be impossible to avoid even if the new monitoring system is used to avoid intraoperative nerve injury. Further research is needed to elucidate the mechanism. In addition, a previous study demonstrated that the retraction time was significantly longer in patients with postoperative symptomatic neuropraxia<sup>17</sup>). However, the current study showed no differences in operative time between the new and conventional monitoring techniques.

The present study has some limitations, including its relatively small patient sample size. The follow-up period of 90 days is relatively short. We did not consider perioperative issues, including operative time. This present prospective comparative observational study did not randomize conventional and new monitoring methods as part of a controlled trial.

## Conclusion

Compared with conventional monitoring methods, the new intramuscular monitoring system using a less invasive probe described here may reduce anterior thigh symptoms.

**Conflicts of Interest:** The authors declare that there are no relevant conflicts of interest.

**Author Contributions:** ES participated in study design and data acquisition. TO participated in analysis of data. HH participated in study design, analysis of data, and preparation of the manuscript. All authors have read, reviewed, and approved the article.

## References

1. Oliveira L, Marchi L, Coutinho E, et al. A radiographic assessment of the ability of the extreme lateral interbody fusion procedure to indirectly decompress the neural elements. *Spine (Phila Pa*

- 1976). 2010;35(26):S331-7.
2. Malham GM, Parker RM, Goss B, et al. Clinical results and limitations of indirect decompression in spinal stenosis with laterally implanted interbody cages: results from a prospective cohort study. *Eur Spine J.* 2015;24(3):339-45.
  3. Formica M, Berjano P, Cavagnaro L, et al. Extreme lateral approach to the spine in degenerative and post traumatic lumbar diseases: selection process, results and complications. *Eur Spine J.* 2014;23(6):684-92.
  4. Knight RQ, Schwaegler P, Hanscom D, et al. Direct lateral lumbar interbody fusion for degenerative conditions: early complication profile. *J Spinal Disord Tech.* 2009;22(1):34-7.
  5. Lehmen JA, Gerber EJ. MIS lateral spine surgery: a systematic literature review of complications, outcomes, and economics. *Eur Spine J.* 2015;3(24):287-313.
  6. Rodgers WB, Gerber EJ, Patterson J. Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases. *Spine (Phila Pa 1976).* 2011;36(1):26-32.
  7. Pumberger M, Hughes AP, Huang RR, et al. Neurologic deficit following lateral lumbar interbody fusion. *Eur Spine J.* 2012;21(6):1192-9.
  8. Le TV, Baaj AA, Dakwar E, et al. Subsidence of polyetheretherketone intervertebral cages in minimally invasive lateral retroperitoneal transpoas lumbar interbody fusion. *Spine (Phila Pa 1976).* 2012;37(14):1268-73.
  9. Billinghamurst J, Akbarnia BA. Spine extreme lateral interbody fusion-XLIF. *Curr Orthop Pract.* 2009;20(3):238-51.
  10. Ozgur BM, Aryan HE, Pimenta L, et al. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J.* 2006;6(4):435-43.
  11. Ebata S, Ohba T, Haro H. Integrated anatomy of the neuromuscular, visceral, vascular, and urinary tissues determined by MRI for a surgical approach to lateral lumbar interbody fusion in the presence or absence of spinal deformity. *Spine Surg Relat Res.* 2018; 2:140-7.
  12. Aichmair A, Lykissas MG, Girardi FP, et al. An institutional six-year trend analysis of the neurological outcome after lateral lumbar interbody fusion: a 6-year trend analysis of a single institution. *Spine (Phila Pa 1976).* 2013;38(23):E1483-90.
  13. Uribe JS, Vale FL, Dakwar E. Electromyographic monitoring and its anatomical implications in minimally invasive spine surgery. *Spine (Phila Pa 1976).* 2010;35(26 Suppl):S368-74.
  14. Tohmeh AG, Rodgers WB, Peterson MD. Dynamically evoked, discrete-threshold electromyography in the extreme lateral interbody fusion approach. *J Neurosurg Spine.* 2011;14(1):31-7.
  15. Fujibayashi S, Kawakami N, Asazuma T, et al. Complications associated with lateral interbody fusion: nationwide survey of 2998 cases during the first 2 years of its use in Japan. *Spine (Phila Pa 1976).* 2017;42(19):1478-84.
  16. Oikawa Y, Eguchi Y, Watanabe A, et al. Anatomical evaluation of lumbar nerve roots using diffusion tensor imaging and implications of lateral decubitus for lateral transpoas approach. *Eur Spine.* 2017;26(11):2804-10.
  17. Uribe JS, Isaacs RE, Youssef JA, et al. Can triggered electromyography monitoring throughout retraction predict postoperative symptomatic neuropraxia after XLIF? Results from a prospective multicenter trial. *Eur Spine J.* 2015;24(Suppl 3):378-85.

Spine Surgery and Related Research is an Open Access journal distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view the details of this license, please visit (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).