



Endoscopic transforaminal lumbar interbody fusion without general anesthesia: technical innovations and outcomes

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Abstract: Innovations in surgical techniques and technologies have enabled spine surgeons to offer patients less morbid alternatives to traditional spine procedures. This review will explore the development of the endoscopic transforaminal lumbar interbody fusion (TLIF) without general endotracheal anesthesia (GETA) and discuss the technical refinements and innovations learned from experiences with this technique. The Awake TLIF employs several key technological innovations: (I) conscious sedation; (II) endoscopic visualization; (III) an expandable interbody device; (IV) recombinant human bone morphogenetic protein; (V) long-acting local analgesia; and (VI) percutaneous instrumentation. Technical refinements, including premedication for prophylaxis against nausea, vomiting, and epistaxis, were made as a result of early experiences with this technique. Results from the first 100 patients to undergo the Awake TLIF demonstrated durable clinical benefit beyond one year postoperatively. Operating time, blood loss, and hospital length of stay averages well below those generally seen with conventional MIS TLIF. Patients achieved a significant reduction in Oswestry Disability Index from baseline of -12.3 points ($P < 0.0001$). In this initial 100 patient cohort, four conversions to GETA were required and four complications resulted, three of which occurred during the first 50 cases. To date, over 200 Awake TLIF cases and the first three-level procedure have been performed. Endoscopic TLIF without the use of general anesthesia is a novel but promising approach for short-segment lumbar fusion. Continued technical innovations will likely afford greater improvements in outcomes, both in the acute and long-term recovery periods.

Keywords: Awake, endoscopic; innovations; outcomes; transforaminal lumbar interbody fusion (TLIF)

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Introduction

One of the primary trends in spine surgery over the past several decades has been to reduce morbidity while improving outcomes, with a focus on minimally-invasive (MIS) spine surgery. Specifically, innovations in surgical techniques and technologies have enabled spine surgeons to offer patients less morbid alternatives to traditional spine procedures.

One prominent example of technical evolution within spine surgery is the transforaminal lumbar interbody fusion (TLIF). First described in 1998 by Harms, the technique involved a unilateral approach to the disc space through the ipsilateral facet joint, enabling placement of an interbody spacer to achieve indirect decompression of impinged nerve roots (1). Subsequent technical refinements and the development of tubular retractor systems enabled the first MIS TLIFs to be performed. A combination of less tissue

disruption and shorter recovery times resulted in reduced postoperative pain, improved clinical outcomes, and lower costs (2,3). The first use of the endoscope-assisted TLIF occurred in 2008 and utilized the existing tubular retractor systems (4). Application of the endoscope within TLIF has since undergone rapid evolution, with more recent descriptions of biptoral techniques (5,6).

However, the trend toward more advanced surgical techniques continued with the aim of further reducing pain and accelerating recovery times following TLIF procedures. Currently, ultra-MIS techniques, in combination with other intraoperative interventions that decrease pain and shorten operating times, obviate the need for general endotracheal anesthesia (GETA) during selected spine procedures—a novel technical innovation. This review will describe the development of the senior author's technique for endoscopic TLIF without GETA—the “Awake TLIF”—and discuss the technical refinements and innovations learned from experiences with this technique.

Methods

The Awake TLIF procedure, as performed by the senior author, has been described previously and demonstrated in detail (7,8). Briefly, the patient is positioned prone on a Jackson table. Supplemental oxygen is given via nasal cannula or face mask, as there is no advanced airway. The patient is sedated with a combination of propofol and ketamine. Careful monitoring with open communication between surgeon and anesthesiologist is paramount for safety. Patients are maintained at light to moderate sedation, allowing for intraoperative feedback to warn the surgeon of proximity to neural tissue. Premedication for prophylaxis against nausea, vomiting, and epistaxis are also administered based on early cases that required conversion to GETA.

With the patient positioned and adequately sedated, the target level is identified by fluoroscopy and a spinal needle is placed through Kambin's triangle into the disc space (9). A Nitinol wire is inserted through the spinal needle, which is used to guide a series of dilators into the disc space, and finally introduce the endoscope.

After visualizing anatomic landmarks, decompression is performed endoscopically using specially designed microendoscopic instruments. Adequacy of decompression can be observed by direct visualization through the endoscope. Endplate preparation is next accomplished using a series of curettes and steel brushes on a powered drill system. Adequacy of endplate preparation is confirmed by

placing a balloon within the disc space that is inflated with radiopaque material, demonstrating interbody dimensions on anteroposterior fluoroscopy. At this point, the endoscope can be reintroduced to remove any residual cartilaginous endplate.

After adequate endplate preparation, recombinant human bone morphogenetic protein is placed directly into the anterior disc space, followed by an expandable mesh bone allograft containment device (OptiMesh, Spineology). With the OptiMesh in position, it is progressively filled with bone allograft matrix. Adequate interbody height, graft positioning, and reduction in spondylolisthesis are confirmed by fluoroscopy during the filling process.

Posterior instrumentation is then inserted percutaneously under anteroposterior and lateral fluoroscopy. Importantly, long-acting liposomal bupivacaine is injected along the screw tracts prior to incision, in order to achieve powerful and durable local analgesia. After final fluoroscopy, the incisions are closed with a 3-0 Monocryl figure-of-eight suture. Of note, these applications of recombinant human bone morphogenetic protein, liposomal bupivacaine, and the OptiMesh device are currently off-label in the United States of America.

Results

Since our earliest experiences with this novel technique, patients have achieved durable clinical benefits at long-term follow-ups (8). Since that initial small series, we have demonstrated significant financial savings at our institution using the Awake TLIF as compared to conventional MIS TLIF with cost reductions of roughly 15% (over US \$3,000) per case (10).

More recently, we have published our results in the first consecutive 100 patients who underwent the Awake TLIF (11). This series demonstrated average operating time, blood loss, and hospital length of stay well below those generally seen with conventional MIS TLIF. These cases spanned a 3-year period, and over 80% of patients achieved 1-year follow-up. Among this cohort, patients achieved a significant reduction in Oswestry Disability Index from baseline of -12.3 points ($P < 0.0001$). As mentioned above, four cases were converted to GETA intraoperatively. These were due to two cases of emesis, one case of epistaxis, and one case of extreme anxiety. All four cases were completed on the same day under GETA without further complication. Other operative complications have included one case of osteomyelitis, one endplate fracture, and two cage

migrations. Of these four operative complications, three occurred in the first 50 cases. At an average 14.6 months postoperatively, there were no signs of delayed nonunion or hardware failure clinically or on radiography (including flexion/extension).

Since the publication of this series, we have passed 200 cases using the Awake TLIF. In these subsequent cases, further technical improvements have allowed us to perform three-level procedures. To-date, we have achieved adequate indirect decompression in over 95% of cases, including those with severe stenosis. We have also experienced our first case of delayed non-union that required reoperation.

Discussion

Technical innovations over the past decade have expanded the utility of endoscopic spine surgery, with particular application to the TLIF. Indeed, there are several key technologies without which the Awake TLIF would be impossible. These include: (I) conscious sedation; (II) endoscopic visualization; (III) an expandable interbody device; (IV) recombinant human bone morphogenetic protein; (V) long-acting local analgesia; and (VI) percutaneous instrumentation. With these technological advances, patient outcomes have improved significantly, as compared to results in the literature with alternative MIS TLIF approaches (12). We believe the elimination of GETA with the Awake TLIF further enhances these benefits. Decreases in operative time and tissue disruption, as well as reductions in postoperative pain and nausea, contribute significantly to accelerated inpatient recovery periods. Importantly, iterative improvements in both the surgical and anesthetic techniques resulted in fewer technique-related complications over the course of our patient series.

Other select centers have examined similar protocols for awake lumbar surgery, including MIS TLIF (13) and endoscopic foraminotomy (14). In contrast to our institution's endoscopic approach, Chan *et al.* describe a MIS TLIF procedure using tubular retractors and direct decompression. However, they similarly employed multimodal analgesia to spare the use of GETA, including both spinal and infiltrative injections of liposomal bupivacaine, conscious sedation, and greater reliance on non-opioid pain medications such as acetaminophen and gabapentin perioperatively (13). The addition of spinal anesthetic enabled longer operative times beyond two hours in their series. Telfeian describes a case report of a patient who underwent endoscopic foraminotomy to

treat heterotopic bone formation following previous MIS TLIF surgery. Local analgesia was administered and total intravenous anesthetic was titrated, allowing for direct patient-surgeon communication during the procedure (14).

Awake anesthetic protocols for lumbar spine surgery provide favorable outcomes related to morbidity and functional status over time, although current literature remains limited to select studies (11,13,14). Variability in practice and comfort level for awake surgery exists, both within neurosurgery and anesthesiology; thus further study on sparing general anesthesia for lumbar fusion will likely provide greater clarity into the most effective interventions and medications. Furthermore, combining Enhanced Recovery After Surgery (ERAS) programs for lumbar fusion with an awake endoscopic TLIF can optimize recovery even further (15).

Endoscopic TLIF without the use of general anesthesia is a novel but promising approach for short-segment lumbar fusion. Continued technical innovations will likely afford greater improvements in outcomes, both in the acute and long-term recovery periods.

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None.

Footnote

Conflicts of Interest: MY Wang: royalty payments from DePuy-Synthes Spine, Inc., Children's Hospital of Los Angeles, Springer Publishing, and Quality Medical Publishing; consultant for DePuy-Synthes Spine, Inc., Stryker Spine, K2M, and Spineology; advisory board member for Vallum; stock in Spinicity and Innovative Surgical Devices; and grants from the Department of Defense. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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