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Retroperitoneal oblique corridor to the L2–S1 intervertebral discs in the lateral position: an anatomic study

Laboratory investigation

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Object. Access to the intervertebral discs from L2–S1 in one surgical position can be challenging. The transpsoas minimally invasive surgical (MIS) approach is preferred by many surgeons, but this approach poses potential risk to neural structures of the lumbar plexus as they course through the psoas. The lumbar plexus and iliac crest often restrict the L4–5 disc access, and the L5–S1 level has not been a viable option from a direct lateral approach. The purpose of the present study was to investigate an MIS oblique corridor to the L2–S1 intervertebral disc space in cadaveric specimens while keeping the specimens in a lateral decubitus position with minimal disruption of the psoas and lumbar plexus.

Methods. Twenty fresh-frozen full-torso cadaveric specimens were dissected, and an oblique anatomical corridor to access the L2–S1 discs was examined. Measurements were taken in a static state and with mild retraction of the psoas. The access corridor was defined at L2–5 as the left lateral border of the aorta (or iliac artery) and the anterior medial border of the psoas. The L5–S1 corridor of access was defined transversely from the midsagittal line of the inferior endplate of L-5 to the medial border of the left common iliac vessel and vertically to the first vascular structure that crosses midline.

Results. The mean access corridor diameters in the static state and with mild psoas retraction, respectively, were as follows: at L2–3, 18.60 mm and 25.50 mm; at L3–4, 19.25 mm and 27.05 mm; and at L4–5, 15.00 mm and 24.45 mm. The L5–S1 corridor mean values were 14.75 mm transversely, from midline to the left common iliac vessel and 23.85 mm from the inferior endplate of L-5 cephalad to the first midline vessel.

Conclusions. The oblique corridor allows access to the L2–S1 discs while keeping the patient in a lateral decubitus position without a break in the table. Minimal psoas retraction without significant tendon disruption allowed for a generous corridor to the disc space. The L5–S1 disc space can be accessed from an oblique angle consistently with gentle retraction of the iliac vessels. This study supports the potential of an MIS oblique retroperitoneal approach to the L2–S1 discs.

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Key Words • **oblique access** • **lumbar interbody fusion** • **lateral access** • **anatomy** • **psoas**

In recent years, with advancements in surgical techniques and instrumentation, minimally invasive surgical (MIS) approaches for spine surgery have become a safe alternative to traditional open techniques and often the preferred choice for many surgeons.[19,22,27,33] Anterior, transforaminal, lateral transpsoas, transsacral, and oblique MIS approaches have been described for access to the intervertebral discs.[2,14,27] Each of these approaches has inherent risks that will be discussed in this paper.

The lateral retroperitoneal transpsoas approach is preferred by many surgeons due to ease of access, shorter

Abbreviations used in this paper: AP = anteroposterior; BMI = body mass index; MIS = minimally invasive surgical; OLIF = oblique lumbar interbody fusion.

This article contains some figures that are displayed in color online but in black-and-white in the print edition.

operation time, larger cage placement, decreased tissue trauma, less vascular injury, minimal blood loss, and faster patient recovery.[14,21,33] The transpsoas approach does, however, pose risk to neural structures of the lumbar plexus as they course through the psoas.[2,12,13,15,21] The large muscle belly of the psoas and overlap of the iliac crest make access to the L4–5 disc difficult and eliminate access to the L5–S1 disc.[2,3,8,10,15] Access to the L4–5 disc in a lateral transpsoas approach often requires a table break or jack-knifed table position to lower the ipsilateral iliac crest. Access to the L5–S1 intervertebral disc usually requires repositioning of the patient and adopting an alternative approach.[2,15,27]

The purpose of this study is to investigate the MIS oblique access corridor to the L2–S1 intervertebral discs in a right lateral decubitus position without table break.

Methods

Twenty fresh-frozen cadaveric specimens (11 male and 9 female) with peritoneal contents intact were studied. Their age range was from 40 to 103 years. Their body mass index (BMI) ranged from 15.00 to 39.72 (Table 1).

For the data collection phase of this study, a team of surgeons followed the described protocol of surgical technique for exposure and access to each L2–S1 intervertebral disc and took the desired measurements. Before dissection was initiated, each specimen's left femoral artery and vein were accessed and injected with liquid latex. The addition of the latex caused the vessels to expand, simulating a functional vascular system. Each specimen was positioned in the right lateral decubitus position, giving a preferable anatomical orientation, with the aorta being the great vessel closest to the incision and approach.

Open dissection of the specimen was performed. One incision along the mid-axillary plane was created from the 12th rib to the level of the L5–S1 disc. Transverse incisions were then created from the cephalad and caudal aspects of the aforementioned incision to the linea alba, creating a large multilayered tissue flap. The following structures were carefully identified, tagged, and reflected as necessary: the external oblique, internal oblique, and transverse abdominal muscles; the transversalis fascia; the iliohypogastric, ilioinguinal, femoral, lateral femoral cutaneous, and genitofemoral nerves; the median sacral artery and vein; the common iliac artery and vein; the anterior longitudinal ligament, and the sacral promontory, sympathetic chain, and ureter. Care was taken to avoid damage to the sympathetic chain, ureter, nerves, and vascular structures.

Once retroperitoneal access and exposure were gained, landmark identifiers were placed. The disc spaces of L2–3, L3–4, and L4–5 were marked by inserting pins in the discs at the center of the oblique corridor. Using anteroposterior (AP) fluoroscopic imaging with a Ferguson angulation, a pin was placed at the midsagittal plane of the inferior endplate of the L-5 vertebrae.

The oblique corridor was measured at L2–3, L3–4, and L4–5. The distance to describe this corridor is the distance between the left lateral border of the aorta, or nearest common iliac vessel if below the bifurcation, and the anterior ventral medial border of the psoas (Figs. 1 and 2). Measurements were performed with the psoas in a static state and then with mild lateral retraction of the psoas (Figs. 2 and 3). The L5–S1 oblique corridor was defined transversely from the midsagittal line of the inferior endplate of L-5 to the medial border of the left common iliac vessel and vertically to the first vessel that crossed midline (Fig. 1, 4, and 5). Each measurement was taken using a disposable, flexible ruler.

Once all measurements were collected and compiled, descriptive statistics were calculated to characterize the oblique corridor at the lumbar levels. A Student t-test was used to compare differences between levels, and a paired Student t-test was used to compare the difference between retracted and static psoas oblique corridor. Statistics were calculated using Minitab 16.

TABLE 1: Characteristics of the 9 male and 11 female cadavers from which specimens were obtained

Variable	Mean	SD	Min	Max
age (yrs)	61.25	17.33	40	103
height (inches)	66.30	3.81	60	74
weight (lbs)	141.50	42.65	82	269
BMI	22.43	5.57	15.00	39.72

Results

The oblique corridor between the psoas and the vessels at the L2–5 levels was observed in all specimens. Table 2 reports the descriptive statistics obtained for the oblique corridor measurements at each level with and without retraction.

No statistically significant difference ($p > 0.05$) was found when comparing the size of the corridor between levels, in either the static or retracted state. However, statistical significance ($p < 0.05$) was found between the static and retracted state at all levels. These data show that the mild lateral retraction that is applied significantly enlarges the oblique corridor between the psoas and vessels at each lumbar level (Table 3). With mild psoas retraction, the L2–3 corridor increased by an average of 59.60%, the L3–4 corridor by 43.96%, and the L4–5 corridor by 58.97%.

The L5–S1 corridor was measured both vertically and transversely in all specimens. These measurements are also reported in Table 2, but no tests for significance were performed on the L5–S1 measurements.

Discussion

Various approaches to the lumbar intervertebral disc have been described to gain access for lumbar interbody fusions. The first published case of a lumbar interbody fusion, reported in the 1930s by Capener et al, was through an open anterior approach.[27] An open posterior approach through a posterior laminectomy was described in 1953 by Cloward et al., and open transforaminal approaches, which are a modification of the posterior approach, have been used as well.[8,19,27,33] These open techniques require a large incision for adequate exposure and can translate

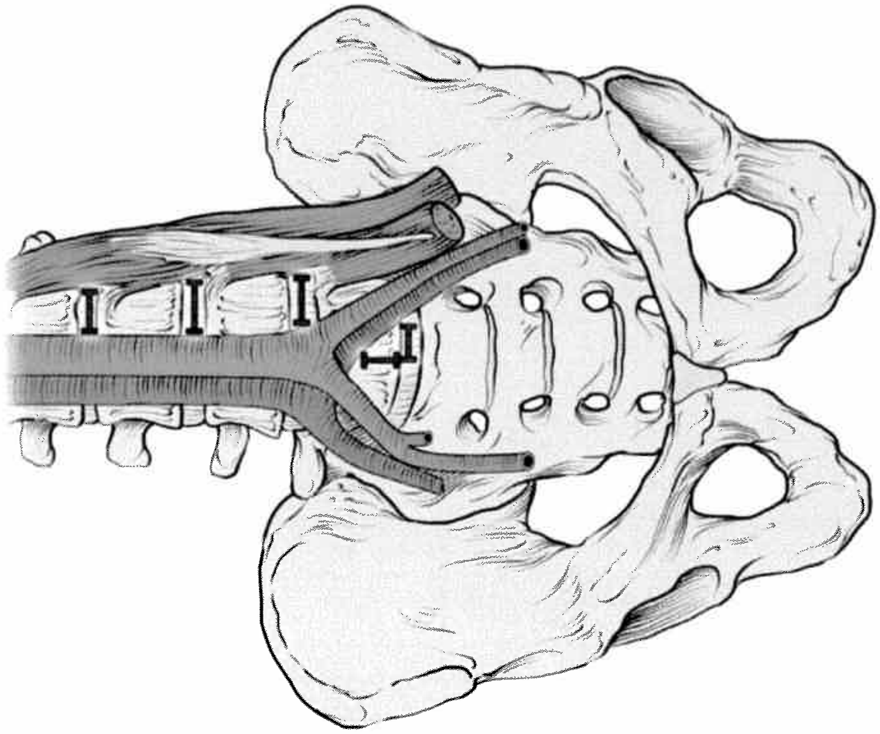

FIG. 1. Illustration depicting L2–3, L3–4, and L4–5 static oblique windows and L5–S1 static sagittal and transverse windows. Image provided by Medtronic, Inc.

to higher morbidity, slower recovery, and longer hospital stays. With open techniques patients are more likely to develop postoperative pain, muscular atony, and abdominal wall defects.[15,28,33]

In recent years, with advancements in surgical techniques and instrumentation, MIS approaches have become a safe alternative to traditional open techniques and often the preferred choice for many surgeons. MIS ap-

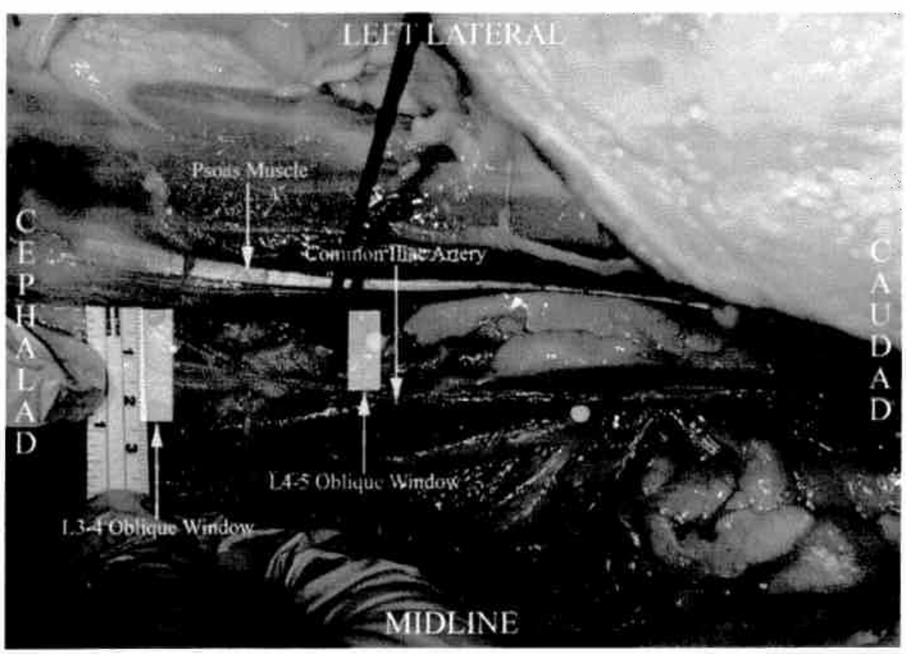

FIG. 2. Measurement of the L3–4 and L4–5 corridors in the static state.

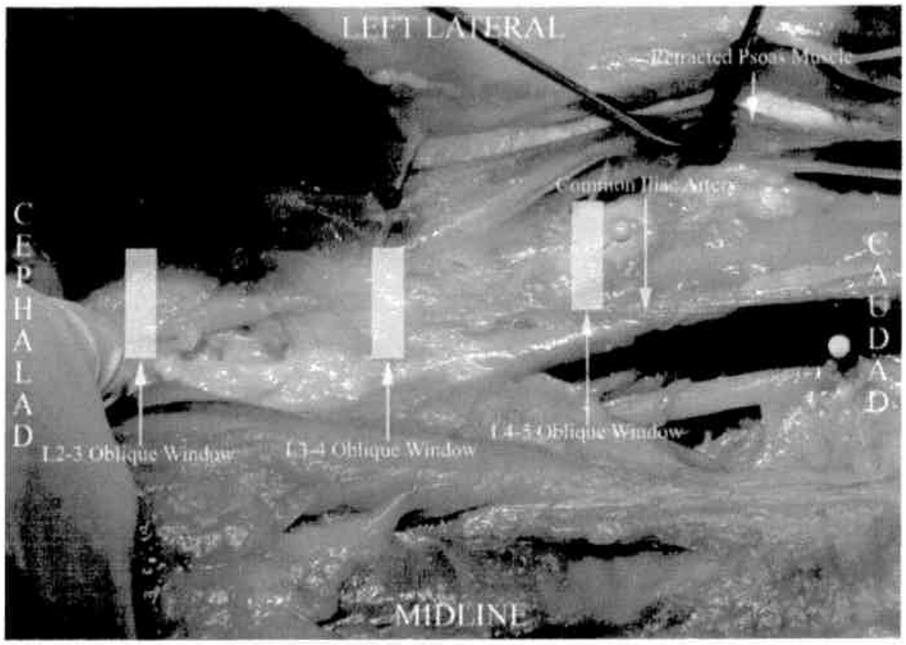

Fig. 3. Measurement of the L2–3, L3–4, and L4–5 oblique corridors with the psoas retracted.

proaches allow for smaller incisions and shorter operating time, which often results in less postoperative pain, less morbidity, shorter hospital stay, and faster recovery.[8,10,15,21] Anterior, transforaminal, lateral transpsoas, transsacral, and oblique MIS approaches have been described for access to the intervertebral discs and anterior spine.

The anterior approach does not violate the posterior elements or require entrance into the spinal canal. It allows for direct visualization of the disc and a larger implant as well as access to the L5–S1 disc, which can be challenging with other approaches.[27] A general surgeon is sometimes needed to provide access for anterior or anterolateral approaches that require entrance into the peritoneum and retroperitoneum, respectively.[5,6,19,33] Even with the assistance of an access surgeon there is risk of injury to the ureter or bladder, peritoneal contents, iliac vessels, ilioinguinal and iliohypogastric nerves, and autonomic nervous system.[22,28,33] Iatrogenic retrograde ejaculation and prolonged

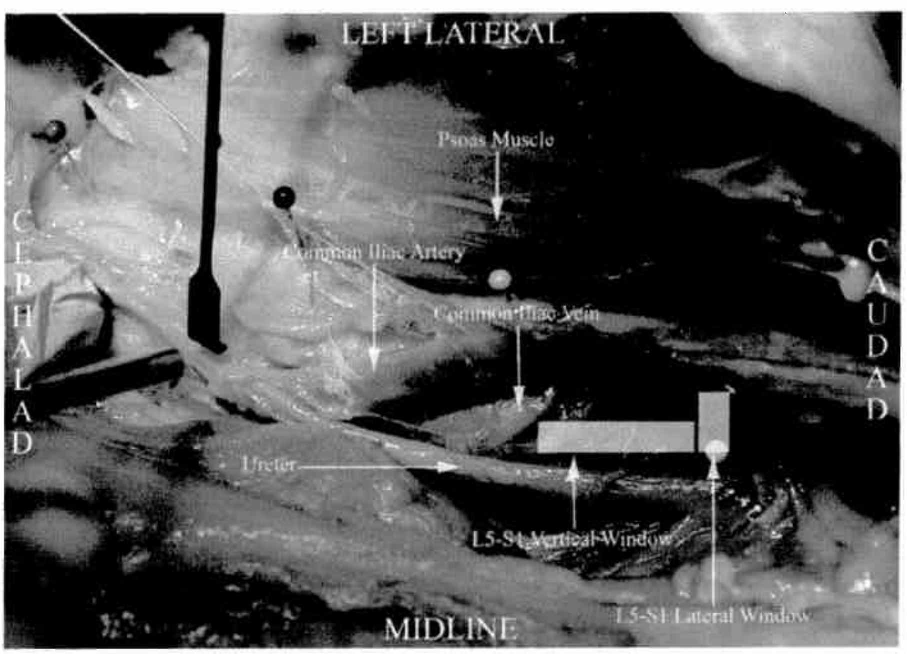

Fig. 4. Measurement of the L5–S1 sagittal and transverse corridors in the static state.

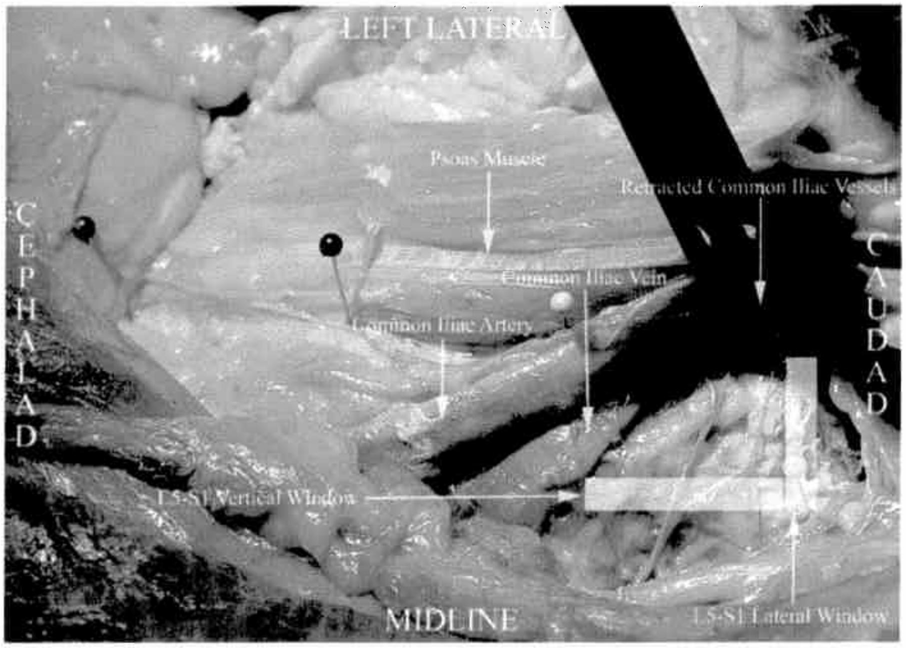

Fig. 5. Measurement of the L5–S1 sagittal and transverse corridors with the common iliac vessels retracted.

ileus due to manipulation of the sympathetic nerves and bowel are reported risks of this approach.[8,10,19]

The transforaminal lumbar approach, first described by Blume and Rojas, is an adaptation of the traditional open posterior approaches.[27] This technique uses an MIS posterior approach with a unilateral facetectomy to provide access to the posterior elements and intervertebral disc. This approach does not give direct access to the disc space, can only accommodate a smaller implant, and leaves less segmental stability due to disruption of the posterior elements.[27]

The transsacral MIS approach is less common and can be used to gain access to the L5–S1 disc space when access via other approaches is limited. This approach is through the fat pad between the rectum and sacrum, and thus mobilization of the bowel is needed for proper access. There is a risk of bowel injury, especially in patients with abdominal adhesions and other abdominal pathology.[15,27]

TABLE 2: Oblique corridor measurements in 20 cadaver specimens

Measurement	Mean (mm)	SD (mm)	Min (mm)	Max (mm)
L2–3				
belly of psoas to vessel	18.60	7.46	4	35
retracted psoas to vessel	25.50	7.39	15	40
amount of psoas retraction	6.90	4.88	0	19
% corridor increase	59.60%	103.30%	0.00%	475.00%
L3–4				
belly of psoas to vessel	19.25	6.54	10	40
retracted psoas to vessel	27.05	8.39	15	50
amount of psoas retraction	7.80	4.50	0	20
% corridor increase	43.96%	28.87%	0.00%	100.00%
L4–5				
belly of psoas to vessel	15.00	7.29	0	35
retracted psoas to vessel	24.45	8.80	7	45
amount of psoas retraction	9.45	6.38	0	25
% corridor increase	58.97%	38.99%	0.00%	166.67%
L5–S1				
midline to common iliac vessel	14.75	6.90	0	25
vertical to midline vascular structure	23.85	13.31	10	58

TABLE 3: Results of Student t-tests for comparison of corridor size between levels and in static versus retracted state at each level

Comparison	p Value
static state	
L2–3 vs L3–4	0.771
L2–3 vs L4–5	0.131
L3–4 vs L4–5	0.060
retracted state	
L2–3 vs L3–4	0.539
L2–3 vs L4–5	0.685
L3–4 vs L4–5	0.345
relaxed vs retracted	
L2–3	<0.0005
L3–4	<0.0005
L4–5	<0.0005

The lateral transpsoas MIS approach, first described by Pimenta et al., does not require an access surgeon and allows for access to the spine without the need to mobilize the great vessels or sympathetic nerves.[19,23,33] Access to the spine is gained through a far-lateral incision that enters the retroperitoneal space and requires dissection through the psoas muscle. The most devastating injury is femoral nerve palsy with complete loss of quadriceps strength.[15,21] There is also risk of injury to the lumbar plexus with this approach due to the anatomical course of the lumbar plexus through the psoas muscle.[2,3,11,12,31] Another disadvantage to this approach is the inability to access the L5–S1 disc space due to the large overlap of the iliac crest and density of neural and vascular structures.[27] Intraoperative neurological monitoring is often used to assess proximity to neural structures and in an attempt to decrease neural injury; however, neurological monitoring is not a substitute for careful dissection and surgical skill.[11,13] Houten et al. described 2 cases where a lateral transpsoas approach was used with intraoperative neurological monitoring and still resulted in L-4 nerve root injury.[13]

Sixteen peer-reviewed articles reporting complication rates of the lateral transpsoas MIS approach were reviewed. The studies were categorized into reports of complex cases of scoliosis and deformity correction with multilevel fusions and reports of less complex cases consisting of primarily 1- or 2-level fusions. The complications were broken down into sensory (dysethesia, paraesthesia, or hypoesthesia), motor (distal weakness), and muscular (iliopsoas weakness or hematoma) deficits. The results are summarized in Tables 4 and 5.[1,2,4,7,9,10,16–19,21,23,24,26,29,30,32]

Mayer previously described an oblique MIS access to the L2–5 discs through a retroperitoneal approach and a transperitoneal approach to access the L5–S1 disc.[20] Saraph et al. compared a traditional open anterior approach with Mayer's MIS approach and found that although fusion and complication rates were similar in their study, the MIS group had shorter operating time, less blood loss,

TABLE 4: Complication rates in 1- and 2-level fusions

Authors & Year	Sensory	Motor	Muscular
Berjano et al., 2012	3%	13%	1%
Cahill et al., 2012	—	2%	—
Cummock et al., 2011	56%	24%	—
Kepler et al., 2011	8%	—	23%
Knight et al., 2009	10%	3%	10%
Moller et al., 2011	25%	—	38%
Pimenta et al., 2011	8%	3%	17%
Pumberger et al., 2012	41%	5%	13%
Sharma et al., 2011	35%	9%	26%
Tohmeh et al., 2011	18%	3%	28%
Youssef et al., 2010	1%	—	1%

and decreased postoperative pain.[25] Silvestre et al. used an MIS approach similar to that of Saraph et al. and in addition described a "sliding window" technique that allowed for access to up to 3 disc levels through the same approach. The results with this technique were also similar to those of Saraph et al., with less blood loss, short operating times, and decreased risk of abdominal wall weakness and herniations.[28] Access to the L5–S1 disc through a MIS oblique retroperitoneal approach was still limited with both of the approaches described above.

Laparoscopic procedures have been described, but these procedures are technically complex, provide limited visualization ability, and have no clear benefits over direct visualization MIS approaches.[28]

Our anatomical study describes an oblique retroperitoneal corridor to the intervertebral discs at L2–L5 as well as L5–S1. This oblique approach can be used to implant an interbody spacer shaped similarly to the spacer placed during a transpsoas approach. Intraoperatively, the patient is placed in a lateral decubitus position, the surgeon stands facing the patient's ventral side, accessing the disc space from an anterior oblique angle. With mild finger and instrument retraction of the psoas and abdominal structures, sequential tubular dilating retractors are placed through the oblique corridor, staying within the oblique corridor, lateral to the vascular structures and medial to the psoas (Figs. 6–8). Compared with the direct lateral approach, the change in trajectory is angular rather than an anterior translation (Fig. 9). The vertex of the surgical trajectory is at the center of the targeted intervertebral disc space. The retractors are then placed along this trajectory through the oblique corridor (Figs. 7 and 10). Tubular retractors can be either secured to the table via

TABLE 5: Complication rates in complex cases

Authors & Year	Sensory	Motor	Muscular
Anand et al., 2010	61%	7%	—
Dakwar et al., 2010	12%	—	—
Isaacs et al., 2010	1%	7%	34%
Tormenti et al., 2010	75%	25%	—
Wang & Mummaneni, 2010	60%	30%	30%

Fig. 6. Illustration of the oblique lumbar interbody fusion (OLIF) technique, showing retraction of the abdominal viscera in preparation for placement of tubular retractors. Image provided by Medtronic, Inc.

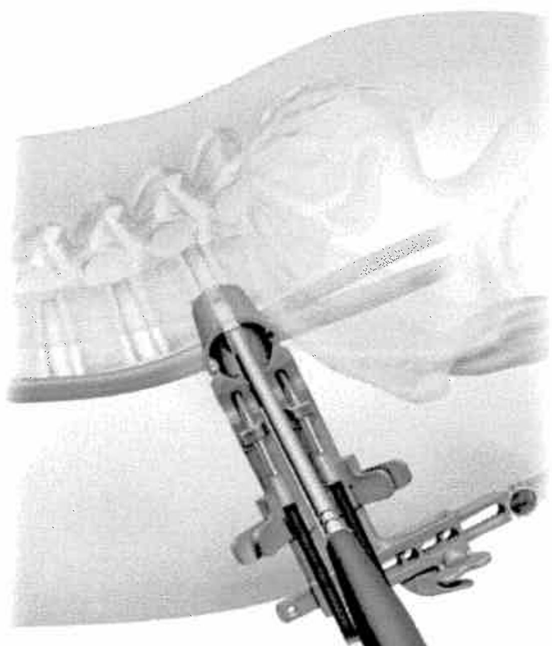

Fig. 7. Illustration of the OLIF technique, showing view of tubular retractor position. Image provided by Medtronic, Inc.

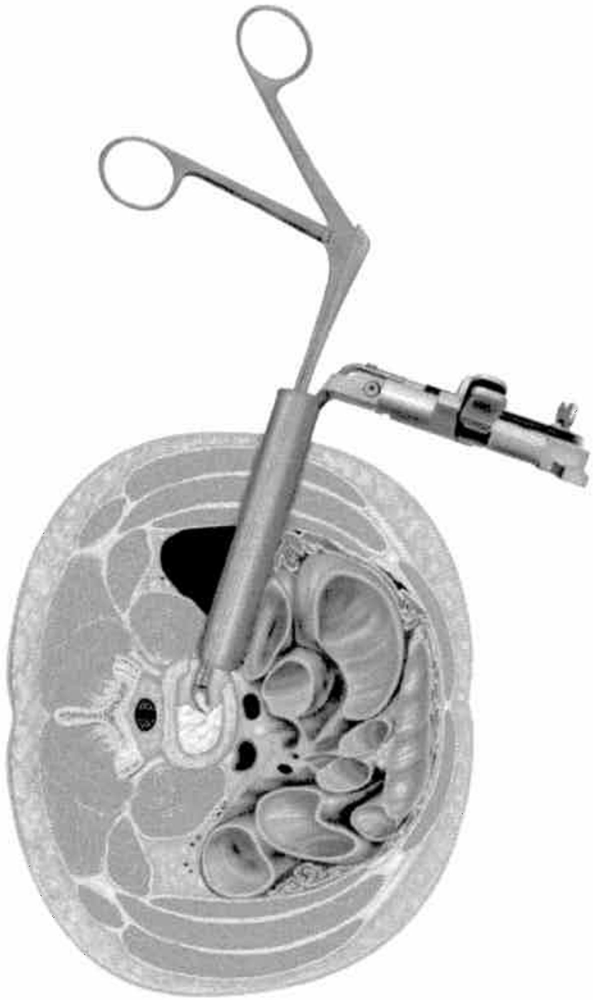

Fig. 8. Illustration of the OLIF technique, showing discectomy through tubular retractors. Image provided by Medtronic, Inc.

fixation arms or directly to the vertebral body above and below the disc space. A complete discectomy and implant placement can be completed through the tubular retractors (Figs. 7 and 10). With the use of this approach, the ureter, peritoneum, and major vessels are often out of the surgical field, and if they are encountered they can be visualized directly and retracted toward midline.

All of our specimens had clear access corridors to the L2–5 disc spaces with the psoas in a static state. In all but one specimen, the diameter of the corridor was increased significantly with mild retraction and this allowed ample space for nucleus removal and lateral interbody spacer placement. With mild psoas retraction, the L2–3 corridor diameter increased by an average of 59.60%, the L3–4 corridor diameter by 43.96%, and the L4–5 corridor diameter by 58.97%. The one isolated specimen with minimal psoas retraction had a psoas that was adherent to the spinal column, but a corridor was still present in the static state. At the L5–S1 level, the transverse and sagittal measurements defined a feasible corridor for disc access in

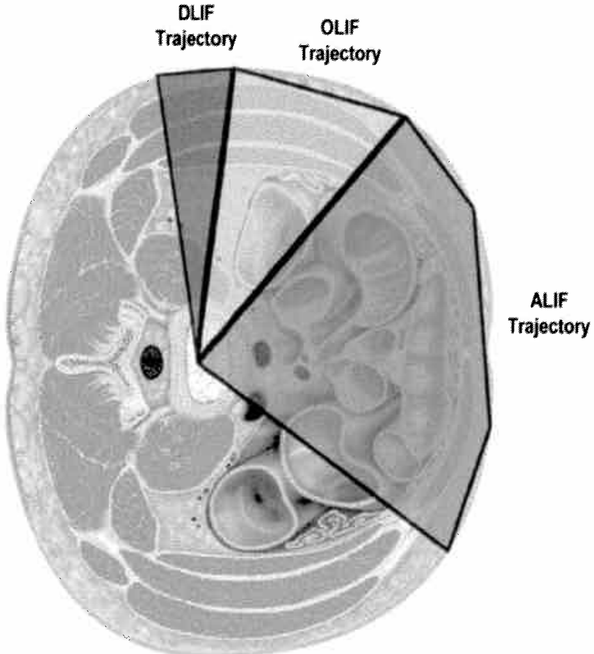

FIG. 9. Illustration comparing the trajectories of anterior, lateral, and oblique approaches to the lumbar disc space. ALIF = anterior lumbar interbody fusion; DLIF = direct lateral interbody fusion. Image provided by Medtronic, Inc.

all specimens. The corridor was largest at the L3–4 level and smallest at the L4–5 level with and without psoas retraction. At all levels, there was a statistically significant difference between the oblique corridor in the static state and the oblique corridor in the retracted state.

Conclusions

Our proposed MIS retroperitoneal oblique corridor allows access to lumbar intervertebral disc spaces from L-2 through L-5 as well as L5–S1 while keeping the specimen in a lateral decubitus position. The oblique anatomical access corridor was present at L–2 to S–1 across all specimens in this study. By taking a retroperitoneal approach and avoiding dissection through the psoas muscle, the MIS oblique corridor avoids many of the anatomical structures associated with posterior, anterior, and transpsoas approaches. Clinical studies are needed to completely understand the risks and possible complications associated with an approach utilizing this oblique corridor.

Disclosure

Dr. Acosta, Dr. Davis, Dr. Kwon, Dr. Spann, Dr. Hynes, Dr. MacMillan, and Dr. Liu report having been consultants for Medtronic. In addition, Dr. Spann and Dr. Liu report receiving support from Medtronic for travel related to this study; Dr. Hynes reports holding patents with, receiving royalties from, and accepting payments for the development of educational presentations and research support for the study described from Medtronic; Dr. Davis reports accepting payment from Medtronic for lectures; and Tom Drochner

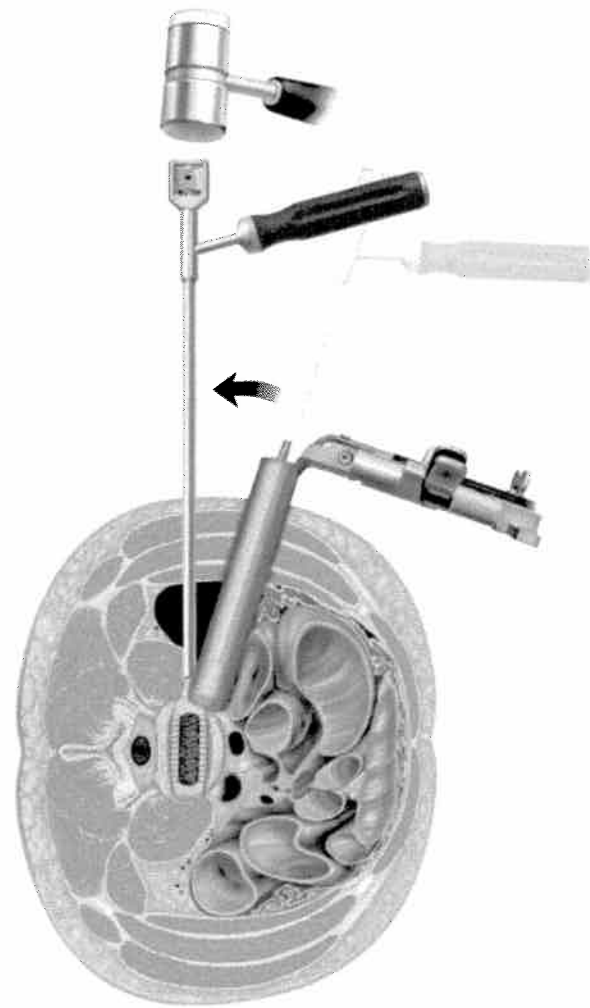

FIG. 10. Illustration of OLIF technique, showing placement of interbody fusion implant. Image provided by Medtronic, Inc.

is currently employed by and owns stock in Medtronic. Dr. Davis also reports a consultant relationship with Stryker, St. Jude Neuro, Vertiflex, and Mesoblast and ownership in Paradigm Spine, Small Bone Innovations, and Alpha Diagnostics. Dr. Kwon also reports a consultant relationship with MDT, JNJ, and ETEX and direct stock ownership in ETEX.

Author contributions to the study and manuscript preparation include the following. Conception and design: Davis, Hynes, Spann, MacMillan, Kwon, Liu, Acosta. Acquisition of data: Davis, Hynes, Spann, MacMillan, Kwon, Liu, Acosta. Analysis and interpretation of data: Fung, Drochner. Drafting the article: Fung, Drochner. Critically revising the article: Fung, Davis. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Fung. Statistical analysis: Fung, Drochner. Administrative/technical/material support: Drochner. Study supervision: Davis.

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