Spine

SPINE Volume 46, Number 15, pp 983–989

ANATOMY

The Feasibility of Anterior Spinal Access

The Vascular Corridor at the L5–S1 Level for Anterior Lumbar Interbody Fusion

Julia Poh-Hwee Ng, MRCS,[a] Matthew Scott-Young, FRACS,[b,c] Daniel Nim-Cho Chan, FRCS,[d] and Jacob Yoong-Leong Oh, FRCS[a]

Study Design. Cross-sectional study.
Objective. To analyze the feasibility of anterior spinal access to the vascular corridor at the L5–S1 junction, by evaluating three crucial anatomical landmarks. This provides a framework for risk-stratification for the clinician during preoperative evaluation.
Summary of Background Data. The anterior lumbar interbody fusion (ALIF) offers many advantages for fusion at the L5–S1 junction. However, the variant iliac vasculature may preclude safe anterior access.
Methods. Five hundred magnetic resonance imaging (MRI) images of the L5–S1 level were identified, with 379 meeting inclusion criteria. We graded the anterior access into three grades, namely, easy, advanced, or difficult by looking at three important anatomical landmarks—the vascular corridor (narrow if $\leq$25 mm, medium if 25–35 mm [inclusive], and wide if >35 mm), the left common iliac vein (LCIV) location (grades A–D based on the relative position of the LCIV to the L5–S1 disc space), and the presence or absence of a fat plane.
Results. Our results showed that 43.27% of the patients had wide corridor for the anterior access, 19.26% of patients had no fat plane, and 7.65% had a LCIV that extended past the midline of the disc (Grade C, D: >50%). By combining these three factors, 37.20% would have easy anterior access, while a minority (1.85%) would have a difficult anterior access.
Conclusion. The ALIF at L5–S1 offers significant benefits to the patient. The surgeon should be aware of the dangers in an anterior access by looking at three crucial factors to determine whether the access is easy, advanced, or difficult. Patients with a difficult access should be attempted by experts, vascular access surgeons, or consider an alternative approach to L5–S1.
Key words: anterior spine surgery, iliocaval vasculature, imaging, interbody fusion, lumbosacral junction, lumbosacral region, magnetic resonance imaging, spine, surgical planning, vascular anatomy.
Level of Evidence: 3
Spine 2021;46:983–989

The anterior lumbar interbody fusion (ALIF) is arguably the best procedure for fusion at the L5–S1 level, offering unparalleled deformity correction, optimal cage placement, and high fusion rates. In addition, the ALIF offers the advantage of a muscle-sparing approach, less blood loss, and less manipulation of the neural structures, thereby reducing the risk of root injury or dural tears. More recently, minimally-invasive techniques have also been described, promising smaller incisions with less muscle dissection and scarring. These benefits translate to reduced postoperative pain, a shorter hospital stay, and ultimately, a faster recovery.

However, anterior access can be challenging as surgeons may not be familiar with the vascular anatomy and its inherent vascular complications. In the majority of cases, the L5–S1 disc lies between the bifurcation of the main arterial and venous structures which allows a surgical corridor to be created. Of the vascular structures, the left common iliac vein is most likely to be injured during anterior access to L5–S1 as it is the most dorsally-located structure,[1–5] and courses anterior-obliquely over the L5 vertebral body.[2] A fat plane that separates the vessels from the vertebrae facilitates dissection, and is the key to the successful mobilization of the blood vessels.

Our study thus aims to identify, based on radiographic preoperative imaging, the incidence of cases in which anterior access to the spine is easy, advanced, or difficult. This provides the surgeon with a framework to review his surgical plan with an aim to minimize vascular complications. To do so, we evaluated, at the L5–S1 level, (1) the size of the vascular corridor, (2) the left common iliac vein (LCIV) position, and (3) the presence of a fat plane.

From the [a]Division of Spine Surgery, Department of Orthopaedic Surgery, Tan Tock Seng Hospital, Singapore; [b]Gold Coast Spine, Gold Coast, Queensland, Australia; [c]Faculty of Health Science and Medicine, Bond University, Gold Coast, Queensland, Australia; and [d]Division of Spine Surgery, Department of Orthopaedic Surgery, Sengkang General Hospital, Singapore.

Acknowledgment date: June 23, 2020. First revision date: August 30, 2020. Second revision date: November 19, 2020. Acceptance date: November 20, 2020.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work.

No relevant financial activities outside the submitted work.

Address correspondence and reprint requests to Jacob Yoong-Leong Oh, FRCS, Spine Division, Department of Orthopaedic Surgery, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore 308433;
E-mail: jacob_oh@yahoo.com

DOI: 10.1097/BRS.0000000000003948

MATERIALS AND METHODS

Patient Selection

This study had obtained institutional research ethics approval (NHG DSRB reference number 2019/01012). Five hundred consecutive non-reformatted magnetic resonance imaging (MRI) lumbosacral spine studies of patients who had not undergone previous spinal instrumentation, done at our institution's Department of Diagnostic Radiology from October 1, 2018 to December 31, 2018, were reviewed.

The MRI images were obtained via GE Medical Systems Signa HDxt 1.5T MR system, with the patient in supine position. The traditional MRI lumbar spine sequences were used for the studies, namely: sagittal T1-weighted, sagittal T2-weighted, sagittal STIR, axial T2-weighted, and axial T1-weighted sequences. Contrasted sequences were added where clinically indicated but were not reviewed in this study. All images were studied in the unenhanced T2 sequence.

Exclusion criteria included age less than 18 years, lumbar scoliosis from any cause, and transitional anatomy (*i.e.*, sacralization of L5, or lumbarization of S1), other obvious pathological anatomy or issues at the time of image acquisition causing significant alterations in the cross-sectional area studied.

Data Collection

Each patient's age and sex were obtained from the clinical records.

Data from each patient were obtained as such:

1. The size of the vascular corridor measured as the horizontal distance between the right-most border of the LCIV and the left-most border of the RCIV at L5–S1 in axial view (Figure 1A).
2. The presence of a fat plane, defined as a sliver of hyperintensity separating the LCIV or its main branch, from the L5–S1 disc, that is visible to the naked eye on the default MRI image, in neutral zoom and contrast (Figure 1B). To reduce intra-observer variability, a single observer had reviewed all the images consecutively in two separate and blinded sittings. Any discrepancies in the interpretation of the fat plane were arbitrated by a third, blinded review by the same reviewer.
3. The location of the main branch of the LCIV with respect to the L5–S1 disc; this is recorded as a ratio of the displacement of the right-most border of the vessel from the left-most border of the L5–S1 disc (Figure 2A–D).

An open-source biological image analysis software, Fiji (National Institutes of Health, Bethesda, Maryland, USA),[6] was used to objectively obtain the measurements. The (x, y) coordinates required to obtain the above measurements in Figure 1 were obtained from each image. By using this software, we are able to localize points on an image with an accuracy of 0.5 pixels by default, and can be made more precise with magnification. The scale in pixels/cm was measured for

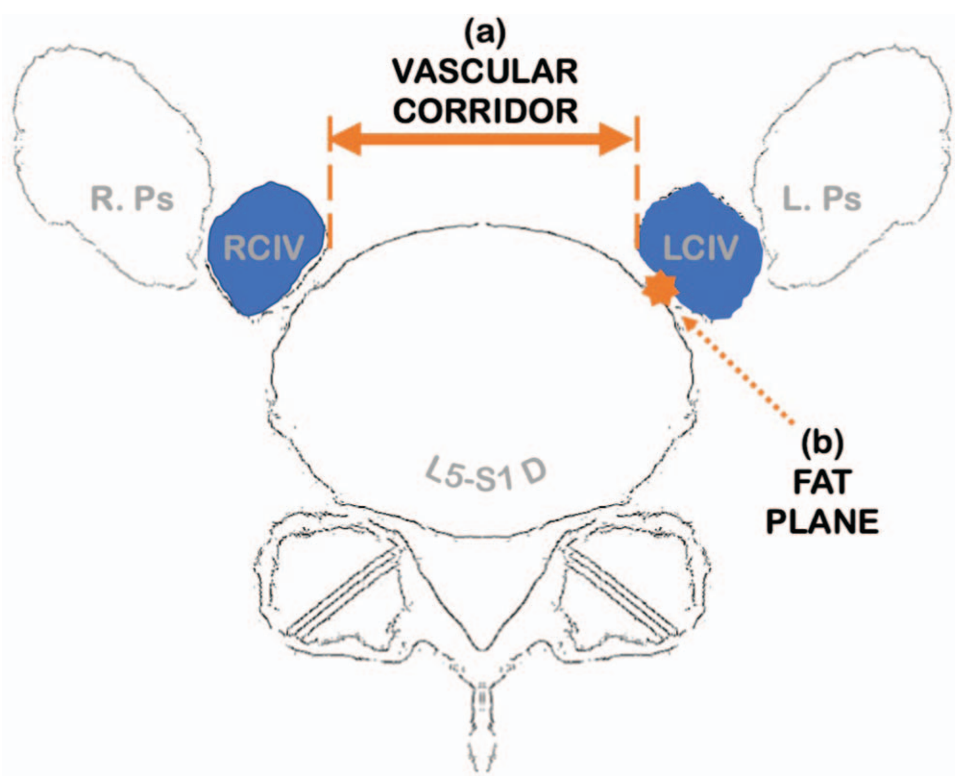

Figure 1. Diagram illustrating the measurement of the (**A**) vascular corridor and (**B**) fat plane on an axial view of the L5–S1 level.

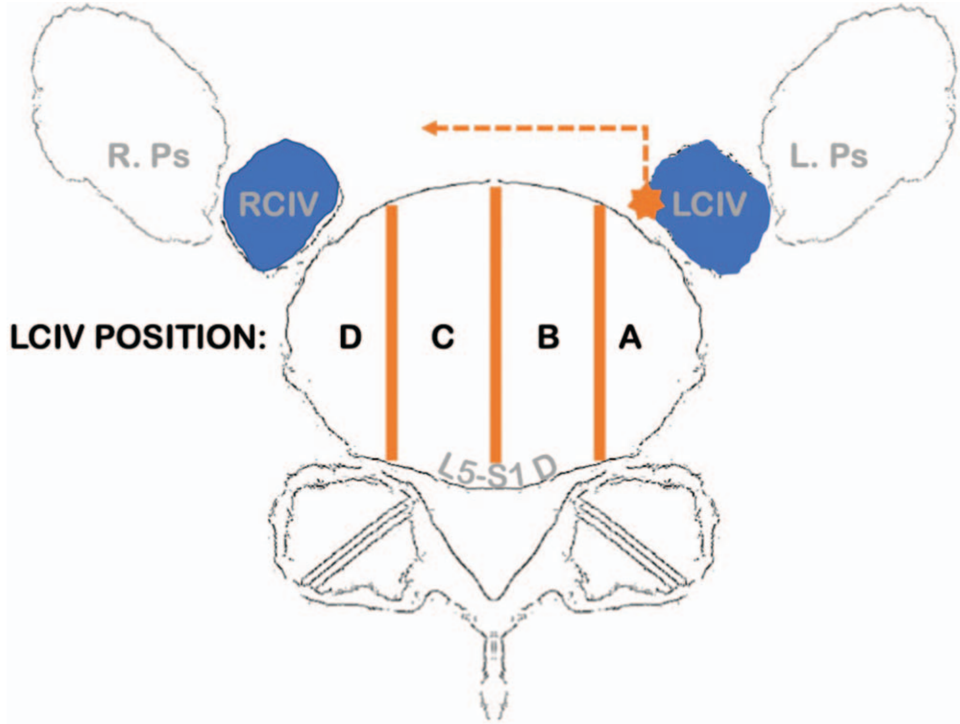

Figure 2. Diagram illustrating the categorization of the position of the main branch of the LCIV with respect to the L5–S1 disc. This is based on the displacement of the right-most border of the vessel from the left-most border of the L5–S1 disc (Figure 1), where: A: ≤25%; B: 25% to 50%; C: 50% to 75%; D: >75%. L. Ps indicates left psoas; LCIV, left common iliac vein; RCIV, right common iliac vein; R. Ps, right psoas.

each image, allowing for conversion of the coordinates into lengths in centimeters of the desired measurement.

The rationale for using an image analyzer and a methodology involving independently identifying landmarks that form the basis for the desired measurements are twofold: firstly, to facilitate reproducibility of the measurements; and secondly, to reduce intraobserver bias that might arise from the categorization of borderline cases into observer-presumed categories.

Data Processing

Using Microsoft Excel, the x, y coordinates obtained were processed through trigonometric formulae to calculate the lengths or angles of interest, as well as to enable the categorizations of the various measurements.

The size of the vascular corridor was categorized as narrow if less than or equal to 25 mm, medium if 25 to 35 mm (inclusive), and wide if more than 35 mm. The rationale behind these cut-off values is to guide the surgeon on the possible size of the interbody cage that can be used. The position of the main branch of the LCIV with respect to the L5–S1 disc was categorized into four grades (Figure 2), where grade A, B, C, and D represent LCIV displacements of less than or equal to 25%, 25% to 50% (inclusive), 50% to 75% (inclusive), and more than 75% from the left-most border of the L5–S1 disc respectively.

Statistical Analysis

All statistical analyses were carried out with JASP (Version 0.9.0.1, University of Amsterdam, the Netherlands).[7] Categorical data were described in percentages, and continuous data described in centiles and mean values.

Based on the three factors examined in this paper, the cases will be classified as follows, in ascending order of access difficulty.

- Easy: present fat plane, and large corridor, and grade A LCIV.
- Advanced: mixed cases which do not fit the complete criteria for "easy" or "difficult."
- Difficult: no fat plane, and small corridor, and grade C or D LCIV.

RESULTS

Out of 500 MRIs, 121 had fulfilled exclusion criteria (Table 1), leaving a total of 379 MRIs for further analysis. The mean age of the patients studied was 56.18 years, with a relatively equal spread of male (n = 201, 53.0%) and female patients (n = 178, 47.0%).

Size of Vascular Corridor

The mean distance was 3.27 cm (SD ± 1.27, range 0.05–7.00). Modifying the classification system used by Barrey *et al*,[8] with size brackets beginning at a ceiling of 15 mm and with intervals of 10 mm, the vascular corridor, which in our study was a measure of the size of the iliocaval bifurcation, was most commonly a wide corridor (>35 mm) (n = 164; 43.27%; Table 2).

LCIV/ Main Branch Position

The LCIV or its main branch was predominantly grade A (n = 225, 59.27%; Table 3, Figure 3A–D). 2.64% of patients were grade D (n = 10).

TABLE 1. Cases Meeting Exclusion Criteria

Reasons for Exclusion	Frequency	Percentage
Abnormal anatomy—L4 vertebral metastasis with extension into anterior fat plane and soft tissue	1	0.83%
Abnormal anatomy—multiple myeloma involving L4 vertebra	1	0.83%
Abnormal anatomy—abdominal mass (infrarenal AAA) adjacent to lumbosacral vertebrae	1	0.83%
Age < 18	1	0.83%
Image-acquisition issues—artefact obscuring vessel	1	0.83%
Image-acquisition issues—no L5–S1 cut	10	8.26%
Image-acquisition issues—oblique cut (axial)	21	17.36%
Image-acquisition issues—oblique cut (sagittal)	5	4.13%
Scoliosis	40	33.06%
Transitional anatomy—lumbarization	17	14.05%
Transitional anatomy—sacralization	23	19.01%

Fat Plane Prevalence and Thickness

19.26% (n = 76) of patients did not have a fat plane that separated the LCIV or its main branch from the L5–S1 disc. The mean size of the fat plane is 0.23 cm (SD ± 0.29, range 0.00–1.91; Figure 4A, B).

Difficulty Level of Anterior Access to L5–S1

Taking together the three factors that determine whether anterior access to the L5–S1 will be difficult, 37.2% of cases have vascular anatomy that will be allow for an easy access (Table 4).

DISCUSSION

Anterior access to the lumbar spine is unmatched for its excellent exposure at the L5–S1 level, allowing insertion of larger cages, accurate cage positioning, and superior deformity correction. For single level fusion, other methods of access to the spine at the L5–S1 level are less favored for various reasons. For example, the iliac crest often precludes lateral access, and a posterior approach affords suboptimal deformity correction, greater blood loss, and possibly a higher rate of infection. Anterior access to the lumbar spine thus remains an integral component of a spine surgeon's armamentarium.

Early cadaveric studies on the vascular anatomy anterior to the lumbar spine had provided a general understanding that the anterior vascular corridor is capacious, but the degree of vessel mobilization required is highly variable.[9] Multiple subsequent studies had further characterized the variant vascular anatomy in the lumbar spine, and specifically at the L5–S1 disc space. This study is unique in that it has identified vascular anatomy relevant to the L5–S1 junction using routine plain MRI lumbosacral studies. While various methods to outline the aortoiliac vascular anatomy have included computer tomographic angiogram (CTA) and special MRI "maximum intensity projection and addition" sequences,[10] these special studies are not routine, and preoperative planning of venous anatomy is almost universally done on a plain MRI.

Our study has also proposed a new method of categorizing the location of the LCIV. The L5–S1 disc is divided in an anterior-posterior manner into four sections of equal width, and the position of the LCIV categorized with reference to the L5–S1 disc. The further lateral to the left the LCIV sits, the less mobilization of the LCIV off the spine will be required, with reduced theoretical risk of venous injury. This study suggests a favorable trend towards easy mobilization with 59.37% of patients having a LCIV located within the left-lateral 25% of the disc. Capellades *et al*[10] reported on a MRI-based series of 134 cases, with a proposed classification that used both iliocaval junctional position and LCIV axial position to describe the patient's venous iliocaval anatomy. They categorized the position of the LCIV only with respect to the left-half of the L5–S1 disc and found that two-thirds of the patients had a lateral-third LCIV, with one-sixth of patients having an intermediate-third or medial-third LCIV each. A predominance of lateral, or grade A, LCIV, agrees with our study.

TABLE 2. Size of the Vascular Corridor (Iliocaval Bifurcation) at L5–S1

Vascular Corridor	Frequency	Percent
Narrow (≤25 mm)	98	25.86%
Medium (25–35 mm)	117	30.87%
Wide (>35 mm)	164	43.27%

TABLE 3. Location of the Left Common Iliac Vein (LCIV) or its Main Branch, as Defined by the Classification of Percentage Displacement of LCIV From Left Disc Border

Classification of % Displacement of LCIV from Left Disc Border	Frequency	Percent
A	225	59.37%
B	125	32.98%
C	20	5.28%
D	9	2.37%

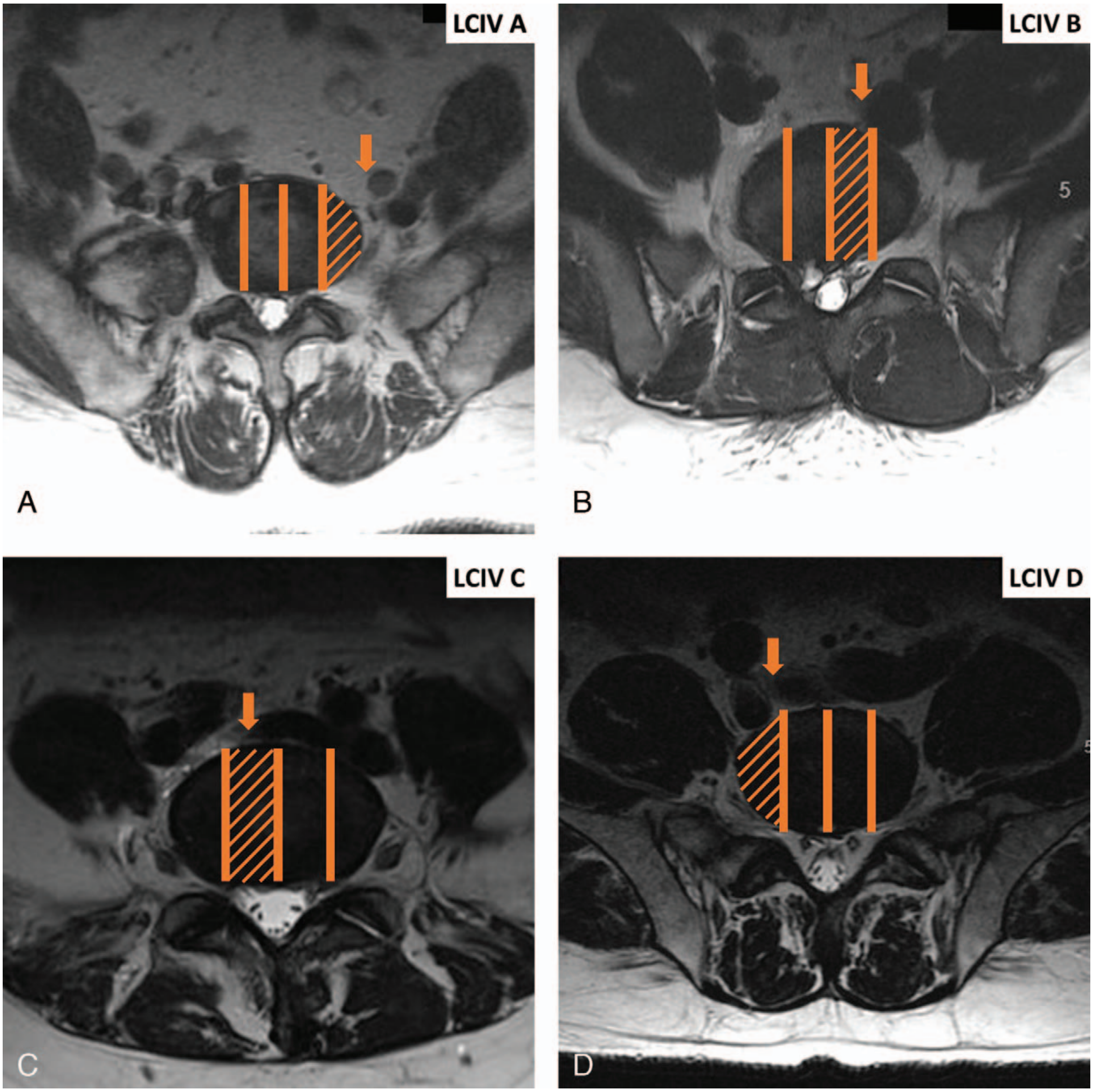

Figure 3. Examples illustrating different grades of the left common iliac vein (LCIV) location; from (**A**) to (**D**), LCIV grades A–D respectively.

Other factors that determine the ease of venous immobilization were also studied. The presence of a fat plane dorsal to the LCIV suggests a low likelihood of tethering between the LCIV and the spine. This thus reduces the risk of venous injury when mobilizing the LCIV off the anterior L5–S1 junction. Lastly, the size of the vascular corridor estimates how much mobilization of the LCIV is required to allow enough width for anterior cage insertion. A mean vascular corridor of 32.7 mm ± 12.7 corroborates with the series of preoperative aortoiliac computed tomography angiography (CTA) by Barrey *et al*,[8] which had a mean vascular corridor of 34.5 mm ± 12 at L5–S1 and a quarter of patients with a narrow corridor (≤25 mm). However, during surgical exposure, the surgeon should bear in mind that for cases with very narrow disc spaces, a wider exposure of the annulus than measured may be required for annulotomy to facilitate disc space mobilization and disc height restoration.

Recognition of the LCIV position, the presence of the fat plane and the vascular corridor width will assist the surgeon in the decision-making process on approaching the L5–S1 anteriorly. This study's findings based on the above three radiographic parameters related to the venous anatomy allow classification of the anticipated difficulty of the surgical approach into easy, advanced, or difficult. We have shown that 37.20% of all cases have venous anatomy that will allow easy access to the anterior spine which will be suitable for early adopters of this technique, while 1.85% of cases have a difficult (complex) anatomy and may require a highly experienced clinician, or a vascular surgeon, to be involved in the procedure. Alternatively, a posterior approach may be considered.

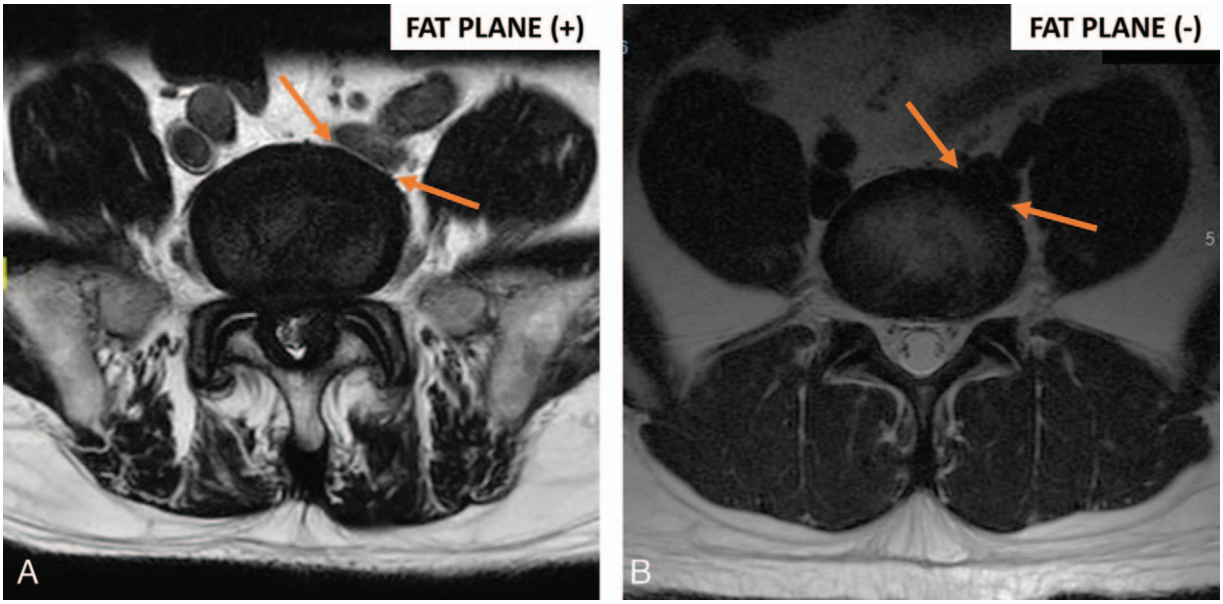

Figure 4. Examples illustrating the (**A**) presence and (**B**) absence of a fat plane.

TABLE 4. Difficulty Grading of Anterior Access to the Spine

	Easy	Advanced	Difficult
Vascular corridor	Wide	Fails full criteria for easy OR difficult	Narrow
LCIV position	A		C or D
Fat plane	Yes		No
Number (%)	141 (37.20%)	231 (60.95%)	7 (1.85%)

LCIV, left common iliac vein.

There are two main limitations to our study. Firstly, the sacral slope and sacral tilt were not analyzed. Of late, a preoperative lateral lumbar spine radiograph with a field of view wide enough to capture the symphysis pubis and the anterior superior iliac spine, has been shown to be useful to assess whether the trajectory to the L5–S1 disc would be blocked anteriorly by the pubic symphysis.[11] However, this is a special view radiograph that is not routinely done and further studies on these measurements will be useful. Secondly, clinical correlation of the proposed radiographic classifications with intraoperative access difficulty will prove to be useful, but was out of the scope of this anatomic-radiographic study.

CONCLUSION

This study evaluates plain MRI lumbar spine images to assess the surgical corridor at L5–S1 to determine the difficulty grading (easy, advanced, or difficult) by taking into account 3 important radiologic variables; namely the size of the vascular corridor, presence of a fat plane and the LCIV location. We have shown that 37% of patients will have an easy anterior access to L5–S1, while 2% of patients will have a difficult access. Preoperative planning is paramount to a successful procedure. We advocate that early adopters of the ALIF technique start with cases that have an easy access, while patients with a difficult access should be attempted by experts, vascular access surgeons, or consider an alternative approach to L5–S1.

➢ Key Points

- ❑ Anterior lumbar interbody fusion at the L5–S1 level has multiple benefits. However, variant iliocaval vasculature at the L5–S1 junction may preclude safe anterior access to the spine at that level.
- ❑ Three factors need to be taken into account during preoperative planning for anterior lumbar interbody fusion at the L5–S1 junction: the size of the vascular corridor, the location of the left iliocaval vein (LCIV), and the presence of a fat plane between the LCIV and the spine.
- ❑ Our study showed that at the L5–S1 level, easy anterior spine access is seen in 37.2% of patients, while a minority of 1.85% of patients will present with significant access difficulty. Preoperative evaluation of the feasibility of access to the anterior spine with relevant imaging is essential to

determine if an experienced surgeon, a vascular access surgeon, or alternative approaches should be considered.

References

1. Brau SA, Delamarter RB, Schiffman ML, et al. Vascular injury during anterior lumbar surgery. *Spine J* 2004;4:409–12.
2. Fantini GA, Pappou IP, Girardi FP, et al. Major vascular injury during anterior lumbar spinal surgery: incidence, risk factors, and management. *Spine (Phila Pa 1976)* 2007;32:2751–8.
3. Hamdan AD, Malek JY, Schermerhorn ML, et al. Vascular injury during anterior exposure of the spine. *J Vasc Surg* 2008;48:650–4.
4. Klezl Z, Swamy GN, Vyskocil T, et al. Incidence of vascular complications arising from anterior spinal surgery in the thoraco-lumbar spine. *Asian Spine J* 2014;8:59–63.
5. Quraishi NA, Konig M, Booker SJ, et al. Access related complications in anterior lumbar surgery performed by spinal surgeons. *Eur Spine J* 2013;22 (suppl):S16–20.
6. Schindelin J, Arganda-Carreras I, Frise E, et al. Fiji: an open-source platform for biological-image analysis. *Nat Methods* 2012;9:676–82.
7. JASP Team (2018). JASP (Version 0.9.0.1)[Computer software].
8. Barrey C, Ene B, Louis-Tisserand G, et al. Vascular anatomy in the lumbar spine investigated by three-dimensional computed tomography angiography: the concept of vascular window. *World Neurosurg* 2013;79:784–91.
9. Tribus CB, Belanger T. The vascular anatomy anterior to the L5-S1 disk space. *Spine (Phila Pa 1976)* 2001;26:1205–8.
10. Capellades J, Pellise F, Rovira A, et al. Magnetic resonance anatomic study of iliocava junction and left iliac vein positions related to L5-S1 disc. *Spine (Phila Pa 1976)* 2000;25:1695–700.
11. Kwon B. Paper #62: Lateral Access Window for ALIF at L5-S1: Anatomical Measurements to Aid Safety and Feasibility. Society for Minimally Invasive Spine Surgery Annual Forum 2019; 2 November 2019, 2019; Las Vegas, Nevada.