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SUPPLEMENT ARTICLE

Spinal exposure for anterior lumbar interbody fusion (ALIF) in the lateral decubitus position: anatomical and technical considerations

Aaron J. Buckland[1] · Carlos Leon[1] · Kimberly Ashayeri[2] · Ivan Cheng[3] · J. Alex Thomas[4] · Brett Braly[5] · Brian Kwon[6] · Constance Maglaras[1] · Leon Eisen[1]

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Abstract

Purpose Single position surgery has demonstrated to reduce hospital length of stay, operative times, blood loss, postoperative pain, ileus, and complications. ALIF and LLIF surgeries offer advantages of placing large interbody devices under direct compression and can be performed by a minimally invasive approach in the lateral position. Furthermore, simultaneous access to the anterior and posterior column is possible in the lateral position without the need for patient repositioning. The purpose of this study is to outline the anatomical and technical considerations for performing anterior lumbar interbody fusion (ALIF) in the lateral decubitus position.

Methods Surgical technique and technical considerations for reconstruction of the anterior column in the lateral position by ALIF at the L4-5 and L5-S1 levels.

Results Topics outlined in this review include: Operating room layout and patient positioning; surgical anatomy and approach; vessel mobilization and retractor placement for L4-5 and L5-S1 lateral ALIF exposure, in addition to comparative technique of disc space preparation, trialing and implant placement compared to the supine ALIF procedure.

Conclusions Anterior exposure performed in the lateral decubitus position allows safe-, minimally invasive access and implant placement in ALIF. The approach requires less peritoneal and vessel retraction than in a supine position, in addition to allowing simultaneous access to the anterior and posterior columns when performing 360° Anterior–Posterior fusion.

Keywords ALIF · LLIF · XLIF · Spinal fusion · Technique · Single position · Lateral decubitus · Spinal exposure · Surgical approach · Minimally invasive spine surgery

Introduction

Circumferential lumbar fusion surgery is an effective treatment option for degenerative and deformity related spinal conditions. Anterior lumbar interbody fusion (ALIF) and lateral lumbar interbody fusion (LLIF) surgeries offer advantages of placing large surface area interbody devices under direct compression of the anterior spinal column. This promotes a healthy fusion environment, improves sagittal alignment and restores disc height, while indirectly decompressing neural elements by increasing foraminal area [1–8]. Additionally, multilevel ALIF and/or LLIF can be performed by a minimally invasive (MIS) approach to the entire anterior column from L1-S1 via smaller incisions, muscle sparing approaches, without the need for patient repositioning. Furthermore, the spine surgeon has the ability to access the anterior and posterior column of the spine in the lateral

✉ Kimberly Ashayeri
Kimberly.ashayeri@nyulangone.org

1 NYU Langone Orthopedic Hospital, New York, NY, USA

2 Department of Neurosurgery, NYU Langone Medical Center, 462 1st Avenue, Suite 7S4, New York, NY 10016, USA

3 Austin Spine Surgery, Austin, TX, USA

4 Atlantic Neurosurgical and Spine Specialists, Wilmington, NC, USA

5 Oklahoma Sports, Science and Orthopaedics, Oklahoma City, OK, USA

6 Division of Spine Surgery, New England Baptist Hospital, Boston, MA, USA

position, enabling instrumentation of both columns, potentially simultaneously, without the need for patient repositioning. The authors have previously published their experiences with single position 360° anterior–posterior fusion surgery and demonstrated reduced hospital length of stay by 1.5 days, operative times by 120 min, blood loss by 100 ml, and rates of ileus by 6%. [8, 9] As more surgeons adopt this new technique, there is a need for a comprehensive, detailed description of technical considerations to ensure safe and effective incorporation of the technique into practice. This work outlines the technical description and considerations for performing anterior lumbar interbody fusion in the lateral decubitus position as detailed by surgeons highly experienced with the single position technique.

Technical description of the lateral ALIF and XLIF procedures

Operating room layout and patient positioning

It is recommended to plan out the optimum setup of the room with the operative team. The determination of which side the patient lies on is dependent of multiple factors which may include prior abdominal surgery, proposed levels fused, prior levels fused, laterality of lower extremity pain, coronal deformity, psoas anatomy and vascular anatomy on advanced imaging. The L5-S1 disc may be approached from either right or left side of the abdomen. When in doubt, the left sided approach to L5-S1 is safer, especially in transitional anatomy due to the position of the left common iliac vein. If lateral ALIF at L4-5, or anterior to psoas approach is planned, then a left sided retroperitoneal approach is recommended. It is important to study the preoperative imaging to determine relationships of vessels to the disc space and any osteophytes, as described above. If posterior instrumentation is planned, the fluoroscopy should be placed on the abdominal side of the patient (Fig. 1). This maximizes the working space available during posterior instrumentation with the fluoroscopy in the AP plane (horizontal position). The fluoroscopy should be draped in for the posterior instrumentation portion of the procedure but need not be draped in during the anterior portion of the procedure.

The patient is positioned in a lateral position on a radiolucent operating table. If only performing anterior reconstruction, then the patient should be placed more anteriorly. If also planning to perform posterior instrumentation then place the patient more posteriorly, approximately five centimeters from the back of the table, to enable placement of the down-sided pedicle screws (Figs. 1, 2). More anterior placement of the patient makes the anterior exposure easier, as a large abdominal apron may hang off the side of the operating table, and the table interferes less with the medial retractor arm. The tradeoff is that anterior positioning may inhibit the down-sided pedicle screws in a lateral position, owing to the interference of the table in their lateral to medial trajectory. Table mounted brackets should be placed anteriorly at the level of the knee for attachment of the medial retractor arm, and posteriorly at the level of the shoulder for attachment of the lateral retractor arm.

Fig. 1 Intraoperative image the operating room setup and table-mounted clamp position for a patient in the right lateral decubitus position

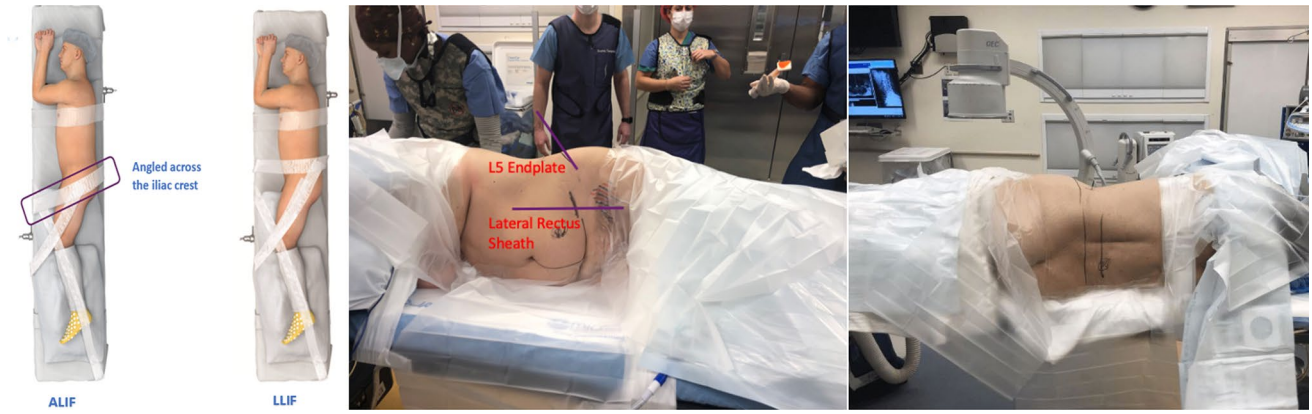

Fig. 2 Illustration from birds-eye view of a patient in the right lateral decubitus position demonstrating patient- and table mounted clamp positioning, as well as comparison of lateral ALIF and LLIF taping techniques (Left). Intraoperative photographs showing anterior (Middle) and posterior (Right) views of patient positioning

Patient taping—Contrasting LLIF and lateral ALIF

Taping is required to stabilize the patient in the lateral position. The taping technique should maximize the ability for extensile exposure as required, while providing stability. The position of taping should ensure that the lumbar spine remains orthogonal to the desired radiographic planes. There are several differences in taping technique depending on whether the surgeon plans to expose the L5-S1 disc space anteriorly, as opposed to exposing L1-5 from a lateral approach.

In lateral access for L1-5, the pelvis is secured by taping transversely across or just above the greater trochanter. While this provides optimized stability of the pelvis, taping in this way interferes with the ability to access the L5-S1 disc space via lateral ALIF. If lateral ALIF L5-S1 is planned, the pelvis should be secured by taping obliquely (Fig. 2). This oblique taping enables better access to the lower abdomen. Extension of the hips also enables more access to the lower abdomen for the ALIF exposure.

Taping of the lower extremities is similar for lateral LLIF and ALIF approaches, in which tape is placed longitudinally along the thigh and lower leg and secured to the operating table. Taping of the chest is performed last of all and placed transversely immediately below the axillary crease. The authors recommend performing this while simultaneously obtaining an AP fluoroscopic image to ensure that the patient is perfectly orthogonal to the AP fluoroscopic image without rotation. This is confirmed as the spinous process should be centralized with symmetrical pedicle shadows at the desired operative level (Fig. 3).

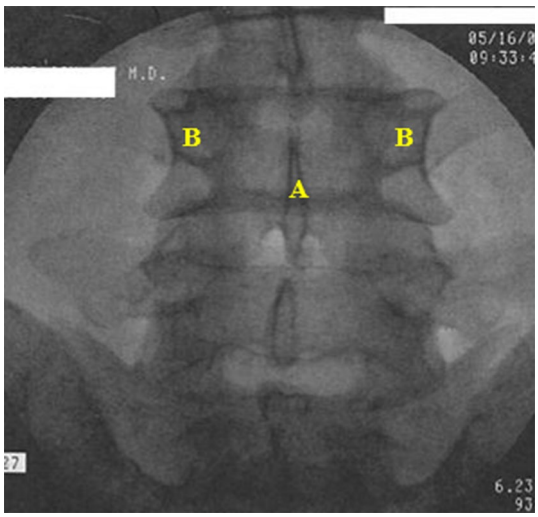

Fig. 3 Fluoroscopic AP image of the lower lumbar spine without rotation. Absence of rotation is confirmed by a central spinous process (A) and symmetrical pedicle shadows (B)

Incision planning and draping

The alignment of the vertebral endplates is marked under fluoroscopy on a lateral image for all levels that are to be fused. For lateral approach to the L1-L5 disc spaces, single or multiples incisions may be planned after identifying anterior and posterior landmarks of each disc space. At the L5-S1 level, the trajectory of the L5 and S1 endplates should be drawn and extended onto the anterior abdominal wall as demonstrated in Figs. 2, 4, points A–D. Palpate the lateral border of the rectus sheath, if an obese patient this space is often visualized as a 'sulcus'. For single-level exposure, the incision is placed in line with the caudal L5 endplate at the lateral border of the rectus sheath (Fig. 4 red dotted line). For

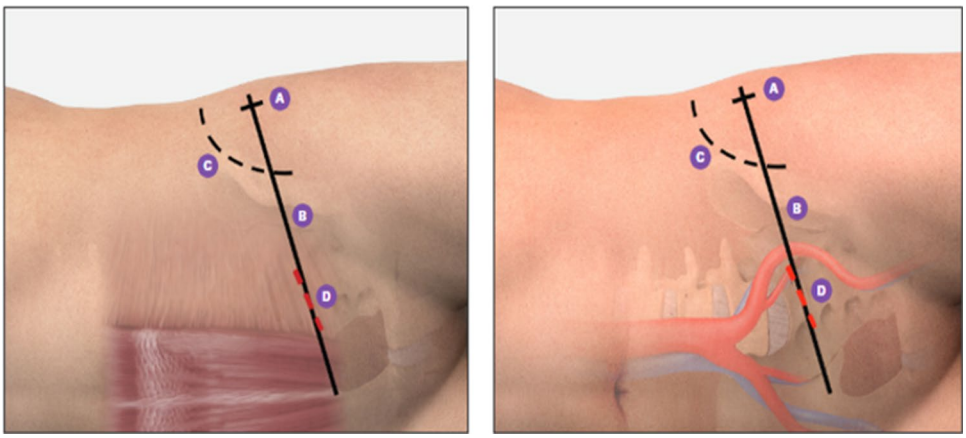

Fig. 4 Clinical illustration of the anterior abdomen in a patient in the right lateral decubitus position for a left sided retroperitoneal approach to L5-S1. A–D = Line of S1 superior endplate, C = cephalad border of iliac crest, B = Anterior border of iliac crest

a multilevel ALIF exposure, a vertical incision may be made along the lateral border of the rectus sheath joining the disc space markings. 270-degree draping is performed to allow access to the abdomen and posterior spine. Anteriorly, the draping should allow access from the xiphoid to the pubic symphysis in a cephalocaudal direction, and to the umbilicus medially in case extensile laparotomy is required in the event of abdominal organ or vascular injury. Posteriorly, the draping is performed from the chest taping to the natal cleft in the cephalocaudal direction. The draping should be placed as close to the table as possible so ensure sufficient space for the bottom sided vertical paramedian incision.

Surgical approach

Below is a step-by-step description of the lateral decubitus ALIF approach, including deviations from supine ALIF. The contrasts between supine ALIF and lateral decubitus ALIF are also summarized in Table 1.

Skin and subcutaneous tissue

Skin incision and dissection through the subcutaneous tissues in line with the skin incision. The deep fascial layer should be identified, and a pre-fascial plane developed.

Accessing the pre-peritoneal plane

The lateral border of the rectus sheath is identified and palpated. Incision of the lateral oblique aponeurosis is performed either in-line with its fascial fibers or vertically. The internal oblique muscle is then split via blunt dissection. After splitting the internal oblique muscle layer, this will give access to the pre-peritoneal plane, evident by a fat layer. Careful blunt dissection is performed with the fingertip to gently separate the peritoneum from the overlying anterior body wall (Fig. 5). This maneuver can be aided by having an assistant provide counter-traction on the abdominal wall with a Richardson retractor.

Table 1 Summary of deviations from standard supine ALIF exposure that are unique to lateral decubitus ALIF exposure

Surgical step	Step deviation in technique from supine ALIF
Skin incision	Incision based over lateral border of rectus sheath rather than over midline
Accessing the pre-peritoneal space	Internal and external oblique muscles are split immediately lateral to the lateral border of the rectus sheath (cf midline between rectus abdominis muscles)
Vessel mobilization	(1) The contralateral vessel is mobilized first, and retracted. (2) Left (upper sided) vein may keep rolling into surgical field under the lateral retractor blade. Use of a pin through the lateral blade, securing to the L5 vertebral body provides both retraction of the vessel and retractor stability
Disc space preparation	(1) Anatomy may be disorientating initially in lateral position. Mark center of the disc space with radiopaque marker. (2) Bias to preparation of the contralateral disc space due to trajectory of the approach. Attention must be given to preparation of the ipsilateral (upper) side of the disc to enable central graft and cage placement
Trialing and interbody implantation	(1) Left (upper sided) vein has a tendency to roll under the lateral retractor blade upon trial removal. Instead of axially back-slapping the trial, instead lift the handle towards the ceiling and the trial will roll out from the lower (contralateral) side of the disc space. (2) Tendency to impact implant obliquely toward the contralateral side. (3) Counter pressure required for impaction—use assistant to place fist at the lumbosacral junction posteriorly

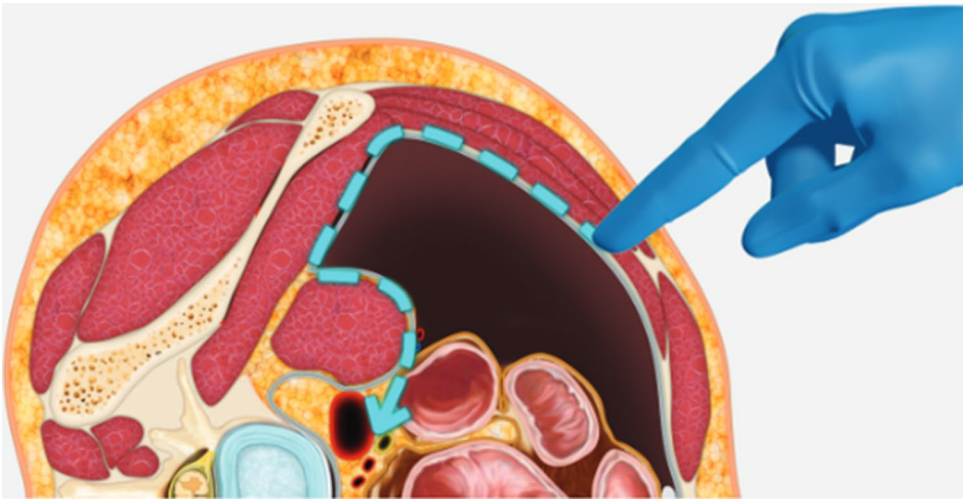

Fig. 5 Illustration of an axial section of the abdomen at the L5-S1 disc level in the lateral decubitus position, demonstrating the pre-peritoneal plane of dissection (blue-dotted outline)

Accessing the retroperitoneal plane

A sponge stick is used to sweep the peritoneum in a top-down fashion releasing it from the anterior and lateral abdominal wall. The ureter is an important structure to visualize during the initial dissection. In addition to protection from injury, visualization of the ureter helps with maintaining the orientation of the dissection. It is located on the lateral most aspect of the peritoneum adjacent to the psoas muscle [10]. Once released the peritoneum and abdominal contents are pulled with the sponge stick in a straight down trajectory (i.e. towards the floor) and over the spine. The ureter will most often be adherent to the posterior aspect of the peritoneum and be easily retracted with the peritoneal sac. If it is identified separately, the plane lateral to the ureter should be developed and the ureter retracted medially with the peritoneum.

Vessel mobilization and vessel retraction

The vessels may be visualized, palpated for confirmation, and the lumbosacral prominence palpated prior to placing the retractor. The retractor frame is then assembled. The retractor frame attaches to an articulating arm that connects to the operating table posteriorly at the level of the shoulder. The retractor frame composes a carbon fiber 1/3 circle with adjustable locking clamps to which the lateral and cephalad blades are connected. The frame is oriented as seen in Fig. 6. The frame is oriented vertically to allow the retractor blades to best conform with the disc space, and against the skin to afford some stability to the frame. After releasing the peritoneum and abdominal contents, the sponge stick is exchanged for the medial (down-sided) blade. The cephalad and lateral blades are now placed to widen the exposure the cephalad blade assists in retracting the abdominal contents while the lateral blade retracts the abdominal wall and iliac artery.

Fig. 6 Intraoperative photograph of patient in the right lateral decubitus position demonstrating retractor frame placement on the anterior abdomen

A peanut is used to mobilize the retroperitoneal tissues off the spine. Unlike with a supine ALIF, the contralateral exposure is usually completed first. The plane of dissection deep to the prevertebral fascia begins just lateral to the ipsilateral internal iliac artery. The tissues are dissected towards the contralateral side with the medial

blade exposing the Middle Sacral vessels for ligation. The remaining tissues are pulled over the edge of the spine on the medial (low) side and secured using the reverse angled medial retractor blade. Attention is then turned to finishing the ipsilateral exposure which is dependent on the trajectory of the left iliac vein (assuming left sided approach). Noting the position on the preoperative imaging is helpful. If the vein is situated lateral to the disc space, any remaining tissues are easily retracted with the lateral and cephalad retractors. In situations where there is a low lying (or horizontal) vein, additional dissection is required to divide any tissues or branches tethering the vein, particular attention should be paid to identifying any lateral sacral venous branches which make mobilizing the vein more challenging. The vein is then mobilized cephalad and lateral to the ipsilateral disc space using the retractor blades attached to the retractor frame. In the presence of a steep disc angle, pinning of the lateral- and occasionally a cephalad retractor blade is helpful to maintain their position (Fig. 7, Left).

Pinning retractor

Sometimes the lateral blade (high side) will require pinning to provide stability of the retractor blade, or if the ipsilateral (top) sided vessel is difficult to keep behind the retractor blade. This is typically required if there is a low left iliac vein, if osteophyte prevents wide left iliac vein retraction, or when there is significant mobility of the disc space expected during preparation or trialing (i.e. unstable isthmic spondylolisthesis). Pinning the lateral blade prevents the left iliac vein from rolling from underneath the blade during disc preparation or trialing. Place the pin into the cephalad vertebra so that with trialing and disc space distraction, the vessel moves with the retractor blade and is less likely to roll under the lateral blade.

Pinning of the cephalad blade is occasionally required in the event of a low bifurcation in order to maintain adequate vessel retraction and prevent it rolling in under the cephalad blade. If there is a high bifurcation, placement of the cephalad blade is optional as it may add some stability to the retractor construct.

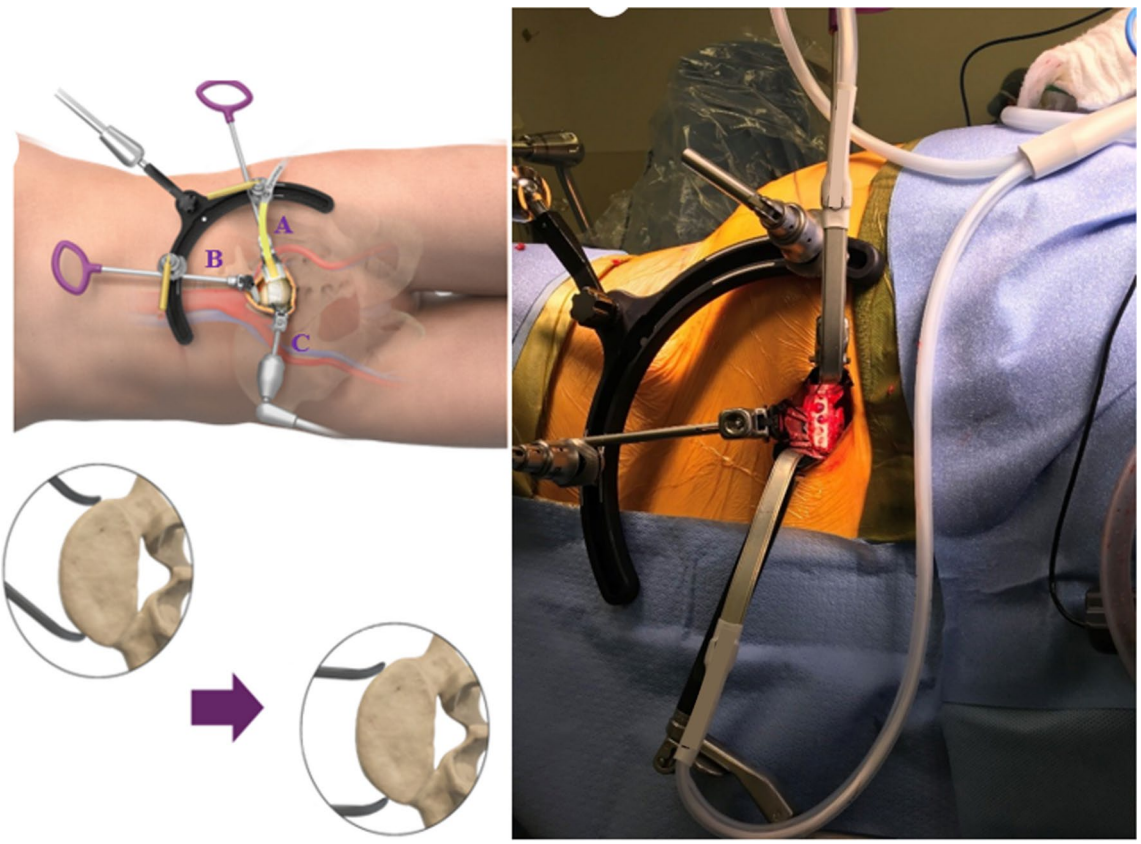

Fig. 7 Illustration (left) and clinical photograph (right) of a patient in the right lateral decubitus position demonstrating retractor placement with vessel retraction. A = lateral retractor blade, B = cephalad retractor blade, C = medial retractor blade. Bottom illustrations depict the angle of trajectory with the retractor blades. The blades are subsequently levered down to provide a more orthogonal approach to the disc space. Intraoperative clinical photograph demonstrating L5-S1 ALIF placement in the right lateral decubitus position

L4-L5 lateral ALIF exposure

Lateral ALIF exposure of L4-5 should only be approached from the left side, similar to supine ALIF exposure. Once again, studying preoperative imaging for relationship of vessels to disc space as well as preserved fat plane between the vessels and spine. Adhesions between the vessels and the spine often occur in the presence of large osteophytes, severe scoliosis, or prior interbody fusion, especially when BMP was used.

When a high IVC confluence (at level of 3–4 disc), exposure of L4-5 can be attempted between the vessels similar to a L5-1 exposure. In most situations, the disc is approached lateral to the vessels. Advantages of L4-5 in lateral position compared to L5-S1 are a straight-on view of the disc space, and gravity helps with the exposure when retracting the left iliac vein/IVC over to the right side of the spine [8]. For the lateral approach, the left Ilio-lumbar vein is ligated along with any additional lateral venous tributaries. Occasionally the L4 segmental vessels also need to be divided similar to in supine ALIF. This is facilitated by initially retracting the iliac artery which puts the vein on tension allowing the lateral border to be visualized. Once the lateral border has been released, blunt dissection with peanut sponges is used to gently pull the vein over to the right side of the disc. Gravity assists with this maneuver and the reversed medial retractor blade is wedged against the vertebral body securing it into place and protecting the vein.

When a high vessel bifurcation is present and the approach occurs between the vessels, then retractor blades are placed (& pinned as required) similar to that at L5-S1. If exposure approach involves retraction of the vessels from the left side, the authors suggest orienting the blades with one regular blade on the lateral side, and two blades (regular or reverse) on the medial (bottom) side at the cephalad and caudal corners of the disc space in order to adequately protect the great vessels.

Disc space preparation, trialing, and implant placement

Level check is recommended using a radiolucent maker in the disc space. The authors recommend also obtaining an AP fluoroscopic image to enable better orientation and marking of the midline. After successful localization, wide annulotomy is performed and the disc material removed with Cobb elevators, disc curettes and shavers similar to supine ALIF. Given the obliquity to the surgical approach, there is a tendency to work towards the contralateral foramen, and attention needs to be paid to preparation of the ipsilateral side of the disc space to ensure centralized implant placement.

In the lateral position, impaction of the trial is different to the supine position owing to the lack of a firm surface to provide counter pressure posteriorly. The authors suggest having the assistant place their fist in the midline at the lumbosacral junction posteriorly to provide counter pressure. When trialing, there is a tendency for the top sided vein to roll-under the lateral retractor, particularly when removing the trial. To avoid injuring the backside of the common iliac vessel, the trial may be removed by lifting the handle of the impactor towards the ceiling and the trial will rotate out.

Implant placement may be performed using a straight inserter; however, the surgeon may prefer an oblique inserter if the patient has excessive abdominal adiposity. Be aware of the tendency to impact the implant toward the contralateral side. Start with impactor in oblique position, impact to gain initial grip on endplates, then drop your hand so that the impactor shaft is horizontal. Then continue to impact the implant until it reaches its desired position. Again, have the assistant place their fist posteriorly at the lumbosacral junction for counter pressure. After separation of the impactor, there is a tendency for the implant to rotated towards the ipsilateral side. Minor adjustments can be made by using a secondary impactor to tap the low side of the anterior border of the implant to rotate it to the neutral position. Instrumentation (either standalone or anterior plate) may be placed via standard technique (Fig. 7, Right).

Percutaneous pedicle screw implantation in the lateral position

The placement of percutaneous pedicle screws in the lateral position is fundamentally similar to placement in the prone position. Comfort with the technique in the prone position is translatable to the lateral position. Initial positioning as described as above is paramount to success of lateral screw placement. Pedicle screw placement can be accomplished with either fluoroscopic guidance or with computer assisted/robot assistance. When using fluoroscopic guidance, standard technique is utilized. Jamshidi needles are placed at the junction of the transverse process and lateral facet and directed medially to a depth of 25 mm. Then, an AP fluoroscopic image should be taken to confirm that there is no medial pedicle breach. Guidewires are placed followed by sequential dilators. Then, the tracts are tapped, and cannulated screws are placed over the wires. Position should be confirmed under fluoroscopy. Screw stimulation with EMG can be performed to assess for pedicle wall violations. When using robotic-guidance, screws should be placed according to standard robot procedure.

Conclusion

Anterior exposure performed in the lateral decubitus position allows safe-, minimally invasive access and implant placement in ALIF. Surgeons utilizing the single-position

technique must be aware of the technical considerations and nuances in order to safely and effectively do so. Furthermore, exposure surgeons should be aware of the inherent biases and technique adaptations required when transitioning from supine to lateral-ALIF exposure to lessen the learning curve.

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Availability of data and material Available.

Declarations

Conflict of interest J. Alex Thomas is a consultant for Nuvasive. Brett Braly is a consultant for Stryker and Nuvasive. Ivan Cheng is a consultant for Nuvasive and Globus Medical. Brian Kwon is a consultant for Nuvasive. Themistocles S. Protopsaltis is a consultant for Altus Partners, Globus Medical, Nuvasive, and Zimmer Biomet. Aaron J. Buckland is a consultant for Nuvasive, Biedermann Motech, Medtronic, Evolution Spine, Altus Partners, and Zimmer Biomet. Leon Eisen is a consultant for Nuvasive.

Consent for publication Permission to reproduce copyrighted material (Figs. 2, 4, 6, 7) was obtained from Nuvasive.

Ethical approval
IRB exempt.

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