Review Article

Anterior lumbar interbody fusion: patient selection and workup

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Abstract: Anterior lumbar interbody fusion (ALIF) is an anterior surgical approach for interbody fusion in the lumbar spine which affords the surgeon unfettered access to the disc space and allows for release of the anterior longitudinal ligament and insertion of a large, lordotic interbody graft. Despite the benefits associated with ALIF when compared with other lumbar interbody fusion techniques, the ALIF approach is associated with a number of unique complications, and certain patient-specific criteria (e.g., vascular anatomy) are important considerations when selecting patients for an ALIF. This review article summarizes the authors' own patient selection criteria for ALIF and describes the items required for pre-operative workup. Notable criteria to consider when planning an ALIF include: patient age, sex, bone density, body mass index, nicotine usage history, the presence—and severity of—medical comorbidities, anatomy of the distal iliac vein/abdominal aorta/iliac bifurcation/iliocaval confluence, history of prior abdominal surgery/infection/radiotherapy, surgical goals, operative level and availability of approach co-surgeons. Pre-operative workup for ALIF procedures should at a minimum consist of magnetic resonance imaging of the lumbar spine, standing X-rays of the lumbar spine with flexion/extension views, scoliosis or long-cassette spinal X-rays and a computed tomography of the lumbar spine without contrast as well as a dual-energy X-ray absorptiometry scan.

Keywords: Anterior lumbar interbody fusion (ALIF); vascular; instrumentation; spinal alignment

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Introduction

Anterior lumbar interbody fusion (ALIF) is a surgical technique widely used to address a variety of lumbar pathologies. The theoretical basis for an anterior approach to spondylolisthesis was first described by Norman Capener in 1932, with the initial procedure performed in 1933 using a tibial autograft through the L5 vertebral body and sacrum (1-3). Over the years, the technique and approach have evolved with various implant materials—including autograft, xenograft, titanium mesh, carbon fiber and later polyether ether ketone (PEEK)—being studied and utilized (3). In 1984, the Hartshill Horseshoe was developed as a stand-alone device (3).

Despite its advancements, the anterior approach was initially considered controversial, with some experts recommending it only for patients with multiple failed prior fusion surgeries (4). Further comparative studies, however, have consistently demonstrated numerous benefits to the anterior approach, including shorter operative times, similar or reduced length of stay (LOS), and less blood loss and transfusion frequency compared with posterior approaches to lumbar interbody fusion (5,6). Additionally, the anterior approach allows for resection of the anterior longitudinal ligament (ALL), providing superior access for extensive discectomy and endplate preparation (7), thus

facilitating the insertion of large, lordotic cages offering greater lordosis correction, disc height restoration, and superior foraminal height correction compared to posterior approaches (5,7-9).

Despite the above benefits to the ALIF approach, however, the procedure itself is not without risk, and patient selection is paramount to the avoidance of adverse events and undesirable outcomes. In this article, we describe our methodology for preoperative workup and patient selection for ALIF.

Complications and associated risks

The overall perioperative complication rate for ALIF in several large series varies widely from 8% to 31% (10,11). Vascular injuries are the most common complications and are largely venous in nature, with a reported incidence ranging from 0 to 18% (12,13). Venous injuries are more common at the L4/5 level and often involve the left common iliac vein, the iliolumbar vein or inferior vena cava (IVC) (12). Arterial injuries, on the other hand, are less common, with a reported incidence of 0–5.2%, typically involving the left common iliac artery (14). Another key complication to be aware of related to ALIF exposure is retrograde ejaculation. This occurs with mechanical or inflammatory injury to the superior hypogastric plexus near the aortic bifurcation (15), and has been reported to occur in 3% of patients, with its incidence being reduced by retroperitoneal versus transperitoneal access to the lumbar spine (15-18). Other complications associated with ALIF include visceral injury (5%) (16), lymphocele formation (19), paralytic ileus (22%, often managed conservatively) (20), venous thromboembolism (VTE), retroperitoneal hematoma, deep or superficial wound infection, and pseudoarthrosis (13,21).

Patient selection criteria

Age

Conventional wisdom would suggest that older patients are more likely to experience perioperative complications after ALIF—or after spine surgery in general. Indeed, results of a retrospective cohort study by Bronheim *et al.* demonstrated that patients >65 years of age undergoing ALIF were more likely to experience a LOS >5 days, increased operative times, cardiac complications, pulmonary complications, urinary tract infections (UTIs), intra/post-operative blood transfusions, reoperations, unplanned readmissions and mortality (22). Other studies, however, have found that advanced age is not an independent predictor of surgical or medical complications after ALIF (7,23). Nevertheless, increasing age can be associated with the accumulation of medical comorbidities (e.g., osteoporosis, frailty) which themselves have been shown to increase the risk of perioperative complications (24,25).

Similarly, some spine surgeons have expressed an unwillingness to perform ALIF on relatively young males as a result of the known risk of retrograde ejaculation occurring after ALIF and the ramifications this may have on the fathering of a child. In practice, the risk of retrograde ejaculation after ALIF is relatively low (2–3%) (16,17), in some cases is transient (26), and in the event that retrograde ejaculation occurs and persists, fathering of a child could conceivably be achieved via intrauterine insemination. Still, these risks must be discussed honestly and openly with patients prior to consideration of the ALIF approach. Of note is that the use of recombinant human bone morphogenetic protein-2 (rhBMP-2) has been associated with increased risks of retrograde ejaculation in some studies (27).

Sex

As mentioned above, patient sex may be a consideration when considering an ALIF approach, partially due to the risk of superior hypogastric plexus injury and resulting retrograde ejaculation. In addition to this, however, Wert *et al.* found in a retrospective review of 106 patients undergoing ALIF that male sex conveyed a 3.78-fold increase in perioperative morbidity risk (28). Similarly, Garg *et al.* found in a prospective study of 212 patients undergoing ALIF that male sex was an independent predictor of major or minor vascular injury during exposure (26).

Bone density

A number of studies have demonstrated that osteoporosis increases the risk of graft subsidence (29-31) and other complications (32) after lumbar interbody fusion. This risk is not unique to ALIF, and in fact, there is limited evidence that ALIF is associated with a lower risk of cage subsidence in general when compared with other lumbar interbody fusion techniques (33). Still, bone mineral density is an important consideration when planning an ALIF, and the authors prefer to treat patients exhibiting osteopenia or osteoporosis with an anabolic agent (teriparatide, abaloparatide or romosozumab)

in consultation with an endocrinologist or other bone health specialist prior to surgery in order to minimize risks of hardware complications perioperatively.

Body mass index (BMI)

Several systematic analyses (34) and retrospective review studies (35-37) have documented an increased risk of perioperative complications in obese patients undergoing spine surgery, including an elevated risk of wound complications, deep venous thrombosis (DVT), pulmonary emboli (PE), and positioning-related peripheral nerve palsies. Similarly, with regard to ALIF in particular, a meta-analysis by Feeley *et al.* documented an increased risk of overall complications in patients with a BMI >30 kg/m^2 (38). A retrospective cohort study by Miller and McAllister found that patients with BMI >35 kg/m^2 undergoing ALIF demonstrated an increased risk of overall wound complications (odds ratio 2.6–3.4) (39). A prospective analysis by Phan *et al.* of 137 patients undergoing ALIF documented an increased risk of pseudarthrosis in obese patients (40). Finally, a retrospective review by Safaee *et al.* of 988 patients undergoing ALIF demonstrated an increased risk of post-operative complications (ileus, wound complications, UTIs) in patients with BMI >30 kg/m^2 (41).

Low BMI may also be a risk factor for complications after ALIF, as low BMI may be a proxy for debility, deconditioning and malnutrition. A retrospective cohort study by Ottesen *et al.* found that patients with BMI <18.5 kg/m^2 undergoing ALIF were more likely to suffer perioperative adverse events in general (42).

Nicotine usage

Nicotine usage has been shown to be associated with increased risks of pseudarthrosis, surgical site infections, worsened clinical outcomes and adverse events for spine surgery in general (43-45). Smoking cessation appears to mitigate these risks partially depending on the duration and timing of cessation (43).

Similarly, with regard to ALIF in particular, retrospective analyses by Phan *et al.* and Kamalapathy *et al.* demonstrated an increased risk of pseudarthrosis and overall complications, respectively, in current smokers undergoing ALIF when compared with their non-smoking counterparts (46,47).

Although tobacco usage is not necessarily a strict contraindication to ALIF, smoking cessation prior to—and after surgery—should be strongly encouraged, as cessation at least 4 weeks prior to surgery has been shown to decrease the risk of surgical site infection and perioperative respiratory and wound complications, and postoperative cessation for at least 6 months is associated with improved fusion rates, satisfaction scores and return-to-work rates (43).

Medical comorbidity profile

Often of primary concern when considering spine surgery in general for a given patient is their overall health and relative "fitness" for surgery and general anesthesia. A retrospective study by Wilson *et al.* suggests that the number of medical comorbidities present in patients undergoing elective spine surgeries has been increasing with time, underlining the increasing necessity for spine surgeon awareness of the impact these comorbidities may have on surgical outcomes (48).

Various risk stratification schemes exist for spine surgery decision making, including the American Society of Anesthesiologists (ASA) Physical Status Classification System (49) and the Charlson Comorbidity Index (50), higher scores for both of which have been correlated with increased risk for perioperative complications after spine surgery (51-55). Little consensus exists however, regarding which stratification system is most predictive or useful in pre-operative risk stratification for spine surgery candidates, and pre-operative clearance from a specialist may be required, particularly in cases of relatively advanced comorbid disease.

Specific medical comorbidities shown to be associated with elevated perioperative risk in spine surgery include diabetes (23,56), chronic obstructive pulmonary disease (COPD) (56,57), cardiovascular disease (56), and chronic corticosteroid use (23,56). Although none of these diagnoses are strict contraindications to ALIF, patient counseling regarding perioperative risk is necessary, and pre-operative consultation and clearance from a specialist may be warranted.

Vascular anatomy

Lower abdominal vascular anatomy is an important consideration when planning an ALIF, as vascular anatomy may vary substantially from one patient to the next, and the precise location of the great vessels and their ability to be safely mobilized may influence the size and borders of the operative corridor and disc space access.

Conventional wisdom would suggest that the vascular

anatomy at L5/S1 is most permissive for ALIF, particularly in patients with an aortic bifurcation and iliocaval confluence above the L5/S1 disc. Cadaveric studies have shown that the aortic bifurcation is most commonly seen anterior to the L4 vertebral body, and the iliocaval confluence most commonly seen anterior to the L5 vertebral body (58). ALIF can often be safely performed at higher lumbar levels, but mobilization of the aorta and IVC are necessary.

At L5/S1, the most common vascular injury to occur during ALIF is a left common iliac vein injury owing to its dorsal position and anterior-oblique course over the L5 vertebral body (59). A left common iliac vein which is situated more medially or right-ward at the L5/S1 space on pre-operative magnetic resonance imaging (MRI) is less favorable for an ALIF than one situated to the far left side of the disc space (a left common iliac vein situated at the midline or right-ward of midline is considered particularly unfavorable). Another consideration is the presence of a fat plane (seen as a sliver of hyperintensity on T1- or T2-weighted MRI) between the venous structures (iliac veins or IVC) and the anterior aspect of the spine, as the absence of such a fat plane may indicate adhesion of the vessel to the ALL, increasing the risk of vascular injury during attempted mobilization (59). A cross-sectional study by Ng *et al.* of 500 lumbar spine MRIs demonstrated the absence of such a fat plane at L5/S1 in 19.26% of MRIs, and a left common iliac vein extending past the midline of the L5/S1 disc (an unfavorable location) in 7.65% of patients (59).

Calcification of the aorta and iliac arteries is another factor to consider, as calcification leads to worsened tensile strength of a vessel and lower resistance to tearing (60,61). Calcification is also an indicator of atherosclerosis, and although venous injuries are more common than arterial injuries during an ALIF, several reports exist of arterial thromboembolic complications occurring during ALIF resulting in limb ischemia and/or compartment syndrome. Though no direct evidence exists regarding a relationship between aortoiliac calcification and arterial thromboembolic complications after ALIF, the relationship between vascular calcification and thromboembolic phenomena (e.g., acute coronary events) (62) is well known, and the authors consider extensive calcification of the aorta and/or iliac arteries to be a relative contraindication to an ALIF approach.

History of prior abdominal surgery, infection or radiotherapy

Prior abdominal or retroperitoneal surgery and history of retroperitoneal infection or radiotherapy are associated with increased scarring and adhesions in the retroperitoneal space, potentially increasing the difficulty of an ALIF exposure and the risk of associated complications. As such, these criteria are considered relative contraindications to an ALIF approach.

Momin *et al.* demonstrated in a retrospective cohort study of 660 patients undergoing ALIF that a history of prior abdominal surgery was associated with a 52% increase in the odds of an intraoperative complication per each prior abdominal surgery performed when adjusting for age, operative time, gender, number of operative levels and utilization of an approach surgeon (63). Interestingly, this increased risk was not limited to prior retroperitoneal surgeries alone, as the most common abdominal surgeries in the study were total abdominal hysterectomy with bilateral salpingo-oophorectomy and cholecystectomy. Patients with a prior history of cholecystectomy had the highest risk of intraoperative complications and patients with a history of hernia repair had the highest risk of post-operative complications in this study (63).

Goals of surgery

When selecting patients for an ALIF approach, goals of surgery are another important consideration. In patients with relative contraindications to an ALIF approach (e.g., unfavorable vascular anatomy) and for whom the goals of surgery can conceivably be achieved via another approach, an alternative surgical approach should be considered.

When compared with other modalities of lumbar fusion, perhaps the greatest benefit of the ALIF approach is its ability to achieve disc height restoration and segmental lordosis correction via release of the longitudinal ligament and unobstructed access to the disc space permitting placement of a relatively large interbody graft (13,64). Although similar increases in segmental lordosis may be achievable via ALL release from a lateral transpsoas approach (65,66), such an approach is seldom feasible at L5/S1 due to the position of the iliac crest. In patients for whom disc height restoration and alignment correction are less of a concern, or for whom direct decompression of the neural elements is desired, transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF) or even *in-situ* posterolateral fusion may be considered instead.

Additional situations where ALIF may be preferred over alternative methods for lumbar fusion are in patients with a history of prior extensive posterior lumbar surgery

or infection, in which case TLIF or PLIF may be more technically challenging and bear an elevated risk of dural tears or nerve root injury.

Operative level

The operative level is another consideration when selecting patients for an ALIF approach. ALIF is often preferred at L5/S1 due to the favorable anatomy of the aortoiliac bifurcation and iliocaval confluence at this level, but ALIF can also be performed at L4/5 or more cranially in the lumbar spine. Some authors have suggested that the lordosis correction achievable via an ALIF at L4/5 is superior to that seen at L5/S1, due to the inherently higher baseline lordosis often present at L5/S1 (67). Still, the ALIF approach at—or cranial to—L4/5, necessitates retraction of the aorta and IVC, and several studies have demonstrated an increased risk of vascular complications when ALIF is performed at L4/5 or above (18,26,68,69). As always, open discussion of such risks with patients is necessary prior to surgery, and these risks and others must be balanced with surgical goals in order to reach final decision regarding operative approach. Many surgeons prefer the use of lateral transpsoas interbody fusion from L1–L5, with TLIF and/or ALIF being preferred at L5/S1 (67).

Approach surgeon availability

Although not technically a patient selection criterion, the unavailability of "access surgeons" for the ALIF approach at certain centers may lead to an unwillingness on the part of spine surgeons to perform an ALIF. The anterior approach to the lumbar spine often requires mobilization of the great vessels and an understanding of retroperitoneal anatomy in general. The approach also harbors a small risk of inadvertent peritoneal transgression and visceral injury. As a result of this, spine surgeons often utilize the assistance of an "access surgeon"—which may be a vascular surgeon or general surgeon—to perform the anterior approach to the lumbar spine. The use of "access surgeons" for ALIF has been suggested to lower the risk of vascular and other complications associated with the approach (26,70-72). Several studies have, however, documented the relative safety and feasibility of an ALIF approach performed by spine surgeons themselves (73,74) and some papers have even suggested that the risk of vascular injuries may be higher when "access surgeons" are involved (71,72). A meta-analysis by Bateman *et al.* found that the risk of reoperation, prosthesis-related complications, neurologic injury and postoperative hematoma/seroma formation were lower when an access surgeon were involved, but significantly higher rates of venous thrombosis were seen (27).

In the authors' experience, an access surgeon is preferred and often utilized for ALIF approaches, not only for their expertise with regard to retroperitoneal anatomy, but also for assistance with vessel, peritoneal or visceral repair in the unfortunate event that such an injury occurs. For settings in which an access surgeon is not available, however, ALIF is not strictly contraindicated, provided that the surgeon performing the approach has a thorough understanding of the surgical approach as well as proficiency with the surgical remedy of vascular and/or visceral complications which may occur.

Pre-operative workup

Many of the above patient-selection criteria are based on patient history (e.g., age, sex, medical comorbidities, smoking status), but several important factors in pre-operative planning for an ALIF require pre-operative testing, including information regarding patient bone density, vascular anatomy, and surgical goals.

The authors recommend obtaining an MRI of the lumbar spine, computed tomography (CT) of the lumbar spine, flexion/extension X-rays and scoliosis X-rays of the lumbar spine, and a CT without contrast of the lumbar spine in all patients for whom an ALIF is being considered. The above items will allow for a thorough assessment of neurologic compression, dynamic instability, segmental and overall alignment, as well as the bony anatomy of the operative level. Pre-operative MRI and CT are often sufficient to characterize vascular anatomy at the operative level and screen for factors such as vascular calcification, but in cases wherein further evaluation of vascular anatomy is desired, a CT-angiogram abdomen/pelvis with venous phase or a CT abdomen/pelvis with intravenous (IV) contrast and venous phase may be obtained. Finally, if patients have a history of abdominal surgery, but the extent of such surgery or presence of implants (e.g., hernia repair mesh or other hardware) are ill-defined, a CT abdomen and pelvis may be desired.

In addition to the above imaging studies, the authors prefer to obtain a pre-operative dual-energy X-ray absorptiometry scan to assess bone quality, with patients found to have osteopenia or osteoporosis being referred to an endocrinologist where appropriate for pre-operative

bone health optimization.

Finally, in patients with medical comorbidities requiring optimization or further characterization for risk-stratification purposes prior to surgery, additional laboratory (e.g., hemoglobin A1c), imaging (e.g., echocardiogram), or other (e.g., cardiac stress test, pulmonary studies) studies may be required. Often in such patients, the work-up required for pre-operative risk stratification and clearance will be performed and evaluated by a medical specialist.

Conclusions

Patient selection is critical to ensuring the best possible outcomes after ALIF. A multitude of patient criteria, including patient age, medical comorbidities, bone density, vascular anatomy, surgical goals, and history of prior abdominal surgeries, infection or radiotherapy must be considered. Pre-operative workup should consist of MRI of the lumbar spine, dynamic X-rays, scoliosis X-rays and a radiographic assessment of bone density, at minimum.

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