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Prior to Surgery

1.1 Preoperative patient preparation and evaluation

Surgical access to the intervertebral disc is performed preferably through a retroperitoneal approach, or, occasionally, via the transperitoneal route. During the access surgery, the abdominal contents are mobilized. Therefore the patient should be prepared as for any other abdominal surgery by being instructed to consume only a liquid diet the day before the operation. Administering a cleansing enema the night before surgery may be beneficial. The patient should be advised not to shave the abdomen before coming to the operating room.

Evaluate the lateral plain film of the lumbar spine for signs of calcification of the iliac vessels and aorta as well as anterior spine osteophytic activity in the area (Figure 1). Both of these findings are predictive of increased surgical risk, so all surgeons should be aware of these conditions prior to surgery.

Although vascular imaging studies (Figure 2) are recommended by some authors, particularly in revision surgeries, they are not necessary on a routine basis, since the location of the incision will not be a function of the vessel location, but of the disc space angle itself, and its projection to the anterior abdomen (see 3.1, Localization of level, incision, p. 11). Upon reaching the retroperitoneum, the access surgeon can decide whether to go between the vessels or lateral to them, depending on where the bifurcation is found in relation to the disc spaces themselves.

Occasionally it is of value to review the MRI to determine the degree of inflammatory reaction at the target level(s).

In males over 40 and postmenopausal women, as well as patients with a history of claudication, palpate pedal pulses prior to surgery. Any deficit noted should be evaluated and documented further with non-invasive arterial studies. This will ensure that any pre-existing arterial disease is identified as such and not confused with thrombotic events precipitated by the retraction of the iliac vessels. Noting the value obtained by the pulse oximeter in the left foot at the start of the procedure is also useful (see 1.2 Anesthesia, p. 3).
1.2
Anesthesia

Administer a general anesthetic with intraoperative monitoring, including a CVP line and an arterial line. Introduce a Foley catheter.

Pulse oximetry on the upper extremity and on the left great or second toe is recommended (Figure 3). Oximetry of the left foot is useful for monitoring oxygen saturation while the iliac vessels are compressed by the retractors, and immediately after compression is released, especially at L4-5. It is not uncommon for the oxygen saturation to drop to zero when the iliac vessels are retracted from left to right, but it should return to near preoperative levels after retraction is released.

Nitrous oxide should be avoided, especially when transperitoneal access is expected.

1.3
Patient positioning

1.3.1 Standard Position

For all levels (L2 to S1) place the patient in the neutral supine position, legs together, with the arms abducted at 90° (on arm boards or folded up and secured over the chest) (Figure 4). Adjust the operating table to allow AP and lateral fluoroscopy of the affected level(s). Both arms should be secured and cushioned, taking care not to cause hyperabduction.

Bolsters should not be used under the lumbar spine, since hyperlordosis will increase the tension on the iliac vessels, increase the axial load on the posterior portion of the lumbar spine, and may hinder adequate discectomy and distraction of the posterior disc space.

Access is usually performed from the left side (Figure 5) where there is better visualization of the retroperitoneal vessels that need to be mobilized from left to right. The disc implantation can be performed from either side depending on the spine surgeon’s preference. The assistant is usually across the table from the surgeon. The scrub nurse and instrument table can be at either side of the foot of the table. The C-arm can be brought in from either side and should be allowed to swing unimpeded under the operating table for lateral views.
1.3.2 Alternative Position

For L5-S1, some authors describe the “Da Vinci” position. The arms are abducted to be level with the shoulders and folded over the chest, and secured and cushioned. Alternatively, the arms may be abducted higher than the shoulders and the elbows flexed above the patient’s head. The legs are spread apart and secured in well-cushioned leg holders, allowing the surgeon to work between the patient’s legs, with the assistant at either side. The scrub nurse, instrument table and C-arm are placed as illustrated (Figure 6). This positioning can provide better visualization into the disc space in the sagittal plane (Figure 7), helping to orient instrumentation in that plane without tilting to either side, but it requires use of a special table and is rarely used in the US.

Figure 6: “Da Vinci” position on special OR table

Figure 7: Patient positioning and draping, “Da Vinci” position
1.4
Instruments, retractor systems, illumination

1.4.1 General approach instruments
Most instruments currently in use in the anterior lumbar spine are designed to allow use through a mini-open anterior approach, which is preferred over a standard approach with a larger incision. Therefore, an appropriate selection of instruments for this approach is a prerequisite for a good clinical result.

A basic major abdominal set that includes the following instruments should be opened:

- Goelet or Roux retractors
- Richardson retractors
- Harrington retractors, large and small
- Additional hand-held vessel and bowel retractors (Wylie or Deaver)
- Balfour retractor with appropriately deep side blades (6” for very obese patients)
- Long and regular Pean and tonsil clamps
- Long ring clamps for sponge sticks
- Long Kocher clamps
- Long right-angle clamps
- Bipolar coagulator-bayonet forceps
- 6”, 8” and 10” length DeBakey and Russian forceps
- Cobb elevators, small and large
- 6”, 8” and 10” vascular needle holders
- Yankauer suction tips, preferably metal
- Regular cautery (Bovie) pencil
- Long Bovie pencil with shielded tip
- Peanut or Kittner sponges
- Lap pads
- Medium and medium-large hemoclips
- 2-0 and 3-0 silk ligatures and sutures.
- Gelfoam and thrombin
- 4-0 and 5-0 monofilament (Prolene, Surgipro) vascular sutures

A major general vascular tray should also be available in the operating room to be opened should the need arise for vascular repair.
1.4.2 Retractors for mini-open access

Carry out the initial retroperitoneal dissection and exposure using a combination of Harrington and Balfour retractors (and/or other hand-holds, according to surgeon preference) as described below. After exposure is complete for the appropriate level(s) this retraction can then be removed and exposure maintained with a self-retaining retractor system (Figure 8) such as the ProAccess or SynFrame.

These systems ensure stable, solid retraction with complete exposure of the target area throughout the implantation process. The special reverse-lipped ALAS retractor blades that are recommended here (see 3 Surgical Technique, p. 11) can be used with any of the commercially-available table-held retractor systems (Figures 9 and 10).

Some authors indicate the occasional use of Steinmann pins or other spiked retractors for localized retraction. **We do not recommend using Steinmann pins or any other sharp, pointed devices, to reduce the risk of vascular injury and thrombosis.**
1.4.3 Illumination

Good illumination is imperative. While the use of optical aids such as a surgical microscope or open endoscopy is also helpful, the use of a focused light source, such as a xenon headlamp, is \textbf{strongly recommended} (Figure 11).

\textbf{Technique Tip:} If a headlamp is not used, video assistance is recommended. Besides providing excellent illumination, an endoscope helps the surgeon judge the extent of intervertebral disc removal.

Figure 11: Headlamp illumination
Mini-open approaches for anterior lumbar surgery have been previously described for use with ALIF implants. Some devices, however, including certain intervertebral spacers and total disc replacement devices, require wider mobilization of the vessels because of the increased width of the device as compared to a threaded cage (Figure 12). For these procedures, surgeons should exercise greater care when mobilizing the vessels to minimize the risk of vascular complications, especially at L4-5, where, as one large study indicated, greater than 90% of vascular injuries occur.

A small transverse incision is preferable because the disc or spacer is a transverse midline structure, so wider exposure is obtained than with a similar sized vertical incision. This is especially true in more obese patients. The transverse incision also allows for easier mobilization of the left rectus muscle along its lateral edge, without denervating it, for easier access to the retroperitoneal space. Lateral mobilization of this muscle also reduces the risk of injury to the peritoneum, which is thicker laterally and more easily dissected from the posterior rectus sheath than it is medially. Furthermore, because of the size of the incision, it is easier to perform the initial retroperitoneal dissection if this muscle is retracted medially.

For two-level approaches, the incision is no longer transverse, and variations from oblique to vertical, paramedian incisions have been described. The oblique incision is described and recommended here. A longitudinal midline incision is also acceptable. For more than two levels, the approach is no longer considered mini-open; this larger incision requires only mobilization of the left rectus muscle from the midline to get to the posterior rectus sheath and then into the retroperitoneal space.

Lacerations to the peritoneum can be repaired more conveniently during closure, since at that point they can probably be incorporated into the repair of the posterior rectus sheath. The surgeon, however, may use his own judgment as to when to repair peritoneal defects, depending on their size and location.

In trying to minimize the occurrence of left iliac artery thrombosis while approaching L4-5, it is important to mobilize this vessel as far towards the femoral canal as possible to allow retraction far to the right without undue stretch. Since the artery has no branches, except for the internal iliac, it is
very easy to do this with blunt dissection using a Kittner or peanut sponge. Mobilizing the artery distally will also allow excellent access to the left common iliac vein and easier identification of the iliolumbar vein(s). The left iliac artery tolerates compression very well for close to an hour, but does not do well when stretched to the right. This distal mobilization minimizes the stretch, helping avoid small intimal tears that can lead to a thrombogenic situation.

Retrograde ejaculation is fortunately an uncommon complication that is almost exclusively related to L5-S1 approaches. The superior hypogastric plexus (right) travels with the peritoneum and the retroperitoneal fat coursing over the bifurcation of the aorta down the midline over the promontory (Figure 13). Although a midline structure, it is somewhat closer to the left than to the right iliac artery (Figure 14). This proximity to the left iliac artery, however, is not very significant.

In order to avoid damage to this structure, blunt dissection should be started right at the anterior wall of the left iliac artery just lateral to the ureter (Figure 15). The ureter and peritoneum are then lifted away, and in doing so, the nerve fibers go with the peritoneum. This blunt finger or Kittner dissection is then carried superiorly and far to the right while hugging the promontory (Figure 16). The sequence of photographs, below, illustrates this technique.

Once the middle sacral vessels are clearly visible, the nerve fibers should be out of harm’s way and clips and cautery can be used to control the vessels. In thinner patients, these fibers can be clearly seen and avoided. There is no advantage to approaching L5-S1 with a retroperitoneal approach from the right just to avoid damage to this nerve plexus.

The retroperitoneal route should be used routinely; the transperitoneal approach should be reserved for cases with prior retroperitoneal surgery or retroperitoneal pathologies that may have obliterated the usual anatomic planes. Prior Pfannenstiel, low cervical C-section, or lower midline incisions for intraperitoneal pelvic surgery should not be a deterrent to the retroperitoneal approach through a separate, small transverse incision. The true Pfannenstiel incision should seldom be used or reused, as it is too low for approaching L5-S1 with a very small size, except for patients with the steepest angles at that disc space.
The right-sided approach to L5-S1 should be reserved for re-operative cases and for patients with prior multiple operations or devices present in the left lower quadrant. Since all the other levels are approached from the left, it is probably more comfortable, due to familiarity, to approach L5-S1 from that side as well. As for the upper levels, L3-4 is easier to expose than L4-5 because there is no need to mobilize the iliac vessels and transect the iliolumbar vein(s) unless the bifurcation is very high. Taking the segmental vessels over the bodies of L3 and L4 is sufficient to provide adequate exposure. L2-3, on the other hand, can only be exposed in the neutral supine position in patients that are not more than 20 to 25% over ideal body weight with an ectodermic body habitus. For those who are obese and whose abdomens are “short and wide,” this approach is difficult.

Ureteral injuries are rare but known to occur. To avoid them, the left ureter should be lifted away anteriorly and towards the right with the peritoneum. Separating the left ureter from the peritoneum and keeping it on the left is likely to cause segmental devascularization, which can lead to necrosis of that particular segment. This is true for all levels, including L5-S1, where it is sometimes tempting to dissect it away from the peritoneum and keep it retracted to the left of the disc space.

Other minor problems of this approach include injury to the left sympathetic trunk, which will cause the left leg to be warmer than the right. This is usually unavoidable and likely to be temporary, yet the patient should be warned in advance to avoid anxiety. Mild lymphedema can be another problem resulting from the necessary wide mobilization of the iliac vessels, which inevitably disrupts the lymph nodes in the area. This usually goes unnoticed, but the patient should be warned because there have been cases where the severity and permanence created a significant clinical problem. Damage to the lumbosacral plexus has also been known to occur and can be prevented by avoiding deep penetration or dissection of the psoas muscle. If the psoas needs to be retracted, usually at the higher levels, identify the disc well and then carefully dissect the muscle away from it with a blunt Cobb elevator.
3 Surgical Technique

3.1 Localization of level, incision

Since the incision is small, 5 to 6 cm for a single level and 6 to 8 cm for two levels, it is important to localize the disc spaces for proper incision placement. Take a lateral fluoroscopic image of the spine, holding a straight metal instrument at the side of the patient, with its tip touching the table (Figures 17 and 18). Move the instrument cephalad or caudad and tilt to match the location and angle of the target disc space. Draw a line on the abdomen, perpendicular to the instrument, to indicate where the incision should be made.

Note: Alternatively, the location of the disc space can be determined by looking at the lateral plain film of the lumbar spine, which shows the location of L4-5 in relation to the iliac crest and also shows the angle of L5-S1. Palpating the iliac crest and judging how far caudad, or cephalad, to go based on its relationship to L4-5 then indicates proper placement of the incision.

For two levels, localize each disc space and mark each level with a transverse line, as if to make separate transverse incisions. Then draw another line, starting at the midline on the lower mark and extending to the lateral edge of the upper mark (Figure 19). It is more forgiving to err placing the incision a bit more caudad rather than more cephalad.

Note: The location of these incisions varies depending on the evaluation of the lateral fluoroscopy or film of the lumbar spine as described above. Proper placement of this small incision is crucial. For a single level procedure begin the incision at the midline and carry it transversely for 5 to 6 cm, depending on the size of the patient. For two-level exposure, the incision should start at the midline at the level of the lower disc and end at the level of the upper disc, approaching the lateral edge of the rectus, for a length of 6 to 8 cm. For three levels, the obliquity increases. Also note that for multiple-level approaches, a vertical incision, near midline, is also appropriate, depending on the preference and experience of the surgeon. However, a classical paramedian approach is not recommended.
3.2 Approach for all levels, L2 to S1

Carry the incision to the anterior rectus sheath using electrocautery and continue the subcutaneous portion of the incision beyond the ends of the skin incision, undermining medially and laterally. This will expose the anterior rectus fascia from beyond the midline out to the lateral edge of the left rectus muscle. Incise the rectus fascia from 1 cm to the right of the midline, enough to see a little of the right rectus muscle, to the edge of the rectus laterally. Elevate the anterior rectus sheath anteriorly away from the muscle belly for a distance of 4 to 6 cm both superiorly and inferiorly to allow for full mobilization of the rectus muscle (Figure 20).

Dissect the medial, lateral and posterior aspect of the rectus muscle, taking care to avoid injuring the inferior epigastric vessels, which run along the undersurface of the muscle. These vessels should be elevated with the muscle and retracted with it using the appropriate retractor (Figure 21). The rectus muscle is now mobilized circumferentially and easily retracted medially and laterally.

Retract the rectus muscle toward the midline. Carefully incise the posterior sheath vertically for 4 to 5 mm (Figure 22), until the peritoneum is seen to shine through.

Grasp the incised edges with a hemostat, then lift it away and very carefully dissect it from the peritoneum; incise it as far inferiorly and superiorly as possible. This layer can be quite tenuous and care must be exercised to prevent peritoneal lacerations. The peritoneum will now bulge upward. Using an index finger, carefully push the peritoneum posteriorly at the edge of the fascial incision and slowly develop a plane between it and the undersurface of the internal oblique and transversus muscles and fascia. This will lead into the retroperitoneal space.
Continue careful blunt finger dissection posteriorly and then start pushing medially, gently elevating the peritoneum away from the psoas muscle (Figure 23). Be careful not to enter the retro-psoas space at this point as this will lead to unnecessary bleeding in a blind pouch. The genitofemoral nerve can be easily identified over the psoas. The ureter can usually be identified as the peritoneum is lifted away from the psoas. Both of these structures should be preserved from injury.

Once the psoas is identified, palpate medially to feel for the disc, vertebral body and the iliac artery. At this point, insert the entire hand (if the size of the incision allows) and make a fist in the retroperitoneal area. Sweep with the closed fist up and down then open the fingers to elevate the peritoneum away in all directions. Use a Harrington retractor to keep the peritoneal contents away from the vessels and allow further blunt dissection. Tuck a dry lap sponge superiorly to keep the retroperitoneal fat and peritoneal contents from creeping down and obscuring the field, and then insert a Balfour retractor with appropriately deep blades to keep the incision open in the cranio-caudad plane (Figures 24 and 25).
3.3 Anterior disc exposure for L4-5

3.3.1 Exposure

For operations on only L4-5, or for operations that combine L4-5 with either L3-4 or L5-S1, the iliolumbar vein (or veins) usually must be ligated and cut, as they serve as a tether that prevents mobilization of the iliac vein away from the anterior surface of the spine, preventing proper exposure.

Retract the peritoneal contents away with a Harrington retractor and dissect bluntly just above the left iliac artery to move the retroperitoneal tissues away from it. Expose the entire length of the common and external iliac arteries as distal as possible, and then start careful blunt dissection along the lateral edge of the artery using a peanut or Kittner sponge, or suction tip. Lymphatics will inevitably be disrupted, but this will expose the left common iliac vein just underneath the artery. Continue the blunt dissection posteriorly to identify the iliolumbar vein (and any branches), which crosses the body of L5 and dives into the left paraspinous area. Variations in the formation of the common iliac vein and the iliolumbar or ascending lumbar veins are common and great care must be taken to identify, ligate and transect these veins and avoid avulsion (Figure 26).

Ligation of the iliolumbar vein should be carried out in place by passing a right angle clamp around it and tying with a silk ligature near the junction of the iliolumbar vein to the common iliac vein (Figures 27 and 28). It is recommended to use both ligature and clip on the proximal vein; clips alone may be used in control of the distal vein prior to transection, taking care not to injure the lumbosacral plexus, which travels in a cephalocaudad direction very close to where the vein dives deep. For any operation that involves L4-5, these maneuvers are imperative.
Now separate the left iliac vein and artery from the spine using gentle peanut sponge and fingertip dissection. The large, metal Yankauer-type suction tip can also be used effectively as a pusher in this area (Figures 29 and 30). In most patients, the vein “peels” away easily from the anterior surface of the spine. In some patients, however, there is intense inflammatory reaction in the plane between the vein and the anterior longitudinal ligament, especially when osteophytes are present, so the dissection can be difficult and tedious. The vascular structures are thus swept from left to right, providing adequate visualization of the disc(s) and vertebral bodies (Figure 31).

Segmental vessels running across the valleys on the anterior surface of the bodies can be transected between clips and swept to the sides with blunt dissection. Make sure you can get at least one finger between the vein and the anterior longitudinal ligament so that you can palpate the right lateral edge of the spine with the iliac vessels above your finger(s).
3.3.1 Exposure continued

Keep the finger on the disc while pushing towards the right to prevent injury to the lumbar veins coming in from that side. Be careful not to tear tissues that don’t give way easily as you may tear those lumbar veins. If this should happen, it can usually be controlled with hemostatic agents without need for suture repair.

The figure at right is a representation of what the complete exposure should look like at L4-5 (Figure 32). The discectomy and implantation procedure can now be performed under careful protection of the exposed and retracted vascular structures.

3.3.2 Table-held retractors

When using a table-held retractor system, remove the Balfour and Harrington retractors at this point. Set up the retractor ring or post and arms according to standard instructions, and pre-assemble four retractor blades of length to accommodate the access depth.

Note: The number of blades depends on surgery level, the length of the incision, and surgeon preference, but four is a typical number for most approaches. Retractor blades with a standard curved lip (“forward” curvature) or a small, reverse-curved lip (ALAS radiolucent blades mentioned earlier) should be used. This technique describes the use of the radiolucent, reverse-lipped blades.

Attach the blade to the table-held retractor system, and then push it to the right to elevate the vascular structures and expose the anterior surface of the spine (Figure 33). Once secured to the table-held retractor, the angled lip of the blade will not allow it to move. This “reverse” lip keeps the blade anchored to the edge of the spine, at the level of the disc, and prevents it from slipping anteriorly once tension is applied (Figure 34).
The anterior disc space should now be fully exposed in a direct AP view, allowing for easier passage of the instruments for insertion of the anterior device. Place a second such blade on the left side of the spine, again at the level of the disc, and attach to the table-held system to complete the exposure (Figure 35).

Use the fluoroscope to determine midline after the first two blades are placed. Place additional retractor blades superiorly or inferiorly as required to complete the exposure. With these blades well anchored to the lateral wall of the vertebral column, the spine surgeon and his assistant can work on the disc without other hands or retractors being in the way and with relative security that vessels will not sneak around the retractors and become exposed to injury (Figure 36).

**Note:** If vessels are compressed at L4-5, do not maintain this compression for more than about 45 minutes in order to avoid an increased incidence of venous or arterial thrombosis. If technical difficulties or other factors prolong the device implantation, it is strongly recommended that retractors be released to allow oxygen saturation to return to normal before continuing device implantation.
3.4 Anterior disc exposure for L5-S1

For operations on L5-S1, the dissection is carried anterior and medial to the left iliac artery with the Harrington-Balfour retractor combination placed into that plane to elevate the peritoneal contents. The disc is palpated and dissection carried toward it with blunt dissection between the iliac vessels and below the aortic bifurcation.

The middle sacral vessels may be taken between clips, ligatures or cautery. Cautery is kept to a minimum in males, to avoid injury to the superior hypogastric plexus fibers. The left iliac vein sometimes needs to be widely mobilized to allow placement of the retractor blade against the left lateral edge of the spine. This vein is seen deep to the artery and swept towards the left with a peanut sponge to expose that side of the disc. Dissection towards the right exposes that side of the disc and a retractor blade can be used to maintain exposure there by, again, anchoring the lip on the lateral aspect of the spine (Figure 37). The iliac vessels are not usually visualized on the right side. The table-held retractor is used to keep the two blades in place with the left rectus muscle again mobilized laterally (Figure 38).

Figure 37: Exposure of L5-S1 disc
Blunt dissection; approach between vessels

Figure 38: L5-S1 with the disc resected.
3.5

Anterior disc exposure for L3-4, L2-3

For operations of L3-4 and L2-3, the iliac vessels usually do not have to be mobilized, however, in some cases, the iliolumbar or ascending lumbar vein(s) will need to be transected to obtain adequate mobilization. This makes approaching these two levels somewhat easier, except that L2-3 is extremely difficult to expose in the more obese patients and should only be used in patients as described in the general considerations section. After the initial dissection is carried out with the Harrington-Balfour retractors, deploy the table held retractors as described above.
Upon completion, remove the retractor blades sequentially, leaving the right-sided blade for last. Check the integrity of the vessels thoroughly for signs of arterial thrombosis or injury due to stretching. Remove the lap sponge and allow the tissues to fall back together anatomically.

Close the individual fascial layers separately with running absorbable sutures, making sure that the anterior rectus sheath is well approximated. The posterior sheath need not be closed if it is tenuous and does not offer any significant strength to the closure. A thick, substantial posterior rectus sheath, however, should be closed. Close the subcutaneous tissues and skin in normal fashion (Figures 39 and 40).
Authors and References

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