1. Introduction

While at the beginning of the last century anterior lumbar interbody fusion (ALIF) was thought to treat Pott’s disease years later with a new indication it was depicted for the treatment of spondylolisthesis (1-3). After these early descriptions, anterior lumbar procedures had been started to apply with increasing frequency. Recently, this and other anterior procedures have become a part of daily practice with the addition of further indications such as disc prosthesis.

Disc degeneration is strictly correlated with age and almost half of the population affected with this condition between the ages of 40-60 (4-6). It seems that anterior procedures will continue increasing in practice; they have already become the first-line treatment in certain circumstances.

Rationale of preference of ALIF is shorter operative time, less blood loss, less postoperative pain, shorter hospital stay and faster returning to daily activities than classic posterior approaches. ALIF, also, provides a superior biomechanical reconstruction of the anterior column, better sagittal balance, better restoration of disc interspace height than posterior approach without paraspinous muscle trauma and denervation. All these benefits are enhanced by minimal invasive anterior approaches. Starting from the 1995, the term, minimal invasive anterior vertebral procedures are describing surgeries performed through shorter incisions with very limited dissections and laparoscopic surgeries (7, 8).

2. Indications of minimal invasive surgery

Indications of the minimal invasive ALIF are the same with classical procedures (include spinal deformity, spinal instability, tumors, infection, and chronic disabling low back pain.)

3. Contraindications of minimal invasive surgery

As a relative contraindication of minimal invasive ALIF, an anterior extraperitoneal (ventromedial) approach should not be performed if the patient has had previous major abdominal surgery or spinal surgery around these levels or if the patient is extremely obese. In obese patients retraction of peritoneal sac and the abdominal wall is quite difficult, while in patients with a previous abdominal surgery, dissection of the peritoneum and retraction of the peritoneal sac may cause vascular and organ injuries. Spinal surgery, even performed by posterior approach, may cause stiff adhesions between the vertebrae and the perivertebral tissue which contains major vessels and their dissection may end up with serious bleeding. It is early to evaluate the results of these techniques while they are still in maturation period. Although, at the high volume centers vascular complications reported as low as 1.9%, in most articles there is no exact numbers of complications such as bowel injuries (9). A thorough understanding of anatomical tissue planes and meticulous surgical technique are necessary to prevent serious complications.
4. Surgical procedures

4.a. Anatomical Considerations
For L4-L5 levels either lumbar or various anterior accesses are feasible. Lumbar approach is performed by extraperitoneal route in lateral decubitus position. Anterior approaches can be performed by either transperitoneal or extraperitoneal routes with assorted incisions. Due to iliac crest L5-S1 levels cannot be reached comfortably by lumbar incision. Anterior approaches to L5-S1 level and L4-S1 two level surgeries are required anterior incisions, especially for two level interventions median vertical incisions are more practical.

Independent from the incision type and place, in relation to peritoneal sac there are two anterior approaches to lumbar spine; transperitoneal and extraperitoneal. Advantages of anterior extraperitoneal approach are; ease of retraction of intraperitoneal organs with peritoneal sac retraction only, lateral discectomy is easier with this approach; dissection plan is simple and keeps the peritoneal cavity clean from blood, bone and disc fragments, additionally opening and closure times are shorter. Disadvantage of extraperitoneal approach, mainly, is weak control for the contralateral site of the vertebra and the vessels.

Anterior transperitoneal approach carries the advantages of great exposure comfort for neurosurgical procedures and ease of dissection of the great vessels but peritoneal soiling, and intraabdominal organ retraction difficulties are its drawbacks. For anterior transperitoneal approach “open window laparotomy” is a safer technique which carries retraction and undisturbed peritoneal organs advantages of the extraperitoneal method while it brings comfort of midline access and prevailing of to vessels and disc space on both side of the midline (10).

During dissection at the anterior side of the corpus vertebra it should be remembered that superior hypogastric plexus is situated in front of the last lumbar vertebra and the promontory of the sacrum, between the iliac vessels. Cleavage of this area is carried out by blunt dissection, otherwise electrocautery or traumatic surgery may result in retrograde ejaculation in male patients.

During dissection at the lateral side of the corpus vertebra, segmental spinal arteries are required a special attention. Segmental spinal arteries should not be violated whenever it is possible. If it is required segmental spinal arteries should be ligated near the aorta rather than near the vertebral foramina to remain local circulation. Segmental spinal arteries should not be ligated on both sides of the same level or on the same side of the adjacent level. Thorough understanding of the anterior vasculature and its relation to lumbosacral spine is necessary for a successful surgery.

4.b. L4-L5 access:
According to disc space and vascular structures three main anatomic variations encountered to access the L4-L5 space (11-14).

1. The most common variation is bifurcations are lower than disc (Figure 1 Line A). There are two

![Figure 1: Schematic presentation of the level of L4-L5 with respect to bifurcations](image)

- **Line A**: L4-L5 level is above the bifurcations,
- **Line B**: Bifurcations and the L4-L5 level are on the same plane,
- **Line C**: L4-L5 level is lower than the bifurcations.
options in this situation moving both vena cava and aorta to the right side of disc or moving the aorta to the left and vena cava to the right (Figure 2 A and B). Obviously, the former is easier because limitation of the surgical field with a great vessel on one site is always safer than having one on two sides.

2- The second most common variation, accounts about 30%, bifurcations are higher than disc (Figure 1 Line C). In this circumstance for safety, at least, both iliac vein and right iliac artery are hanged up (Figure 3).

3- The least common variation is aortic bifurcation is higher and the caval bifurcation is at the same level or lower (Figure 1 Line C). The preferred access is between the left iliac artery and vein (Figure 4). During mobilization of the iliac vein posterior tributaries should be identified to prevent bleeding.

4.c. L5-S1 access:
For a safe and sound surgery at this level in majority of patients dissection of the left common iliac vein is sufficient. However, in order to avoid an injury at the interventions below the bifurcation, bifurcation of the vena cava and left iliac vein has to be dissected and cleared off the surgical field in some cases. Left iliac vein at this level is closer to midline than other vascular structures. The distance between the bifurcation of the vena cava and the L5-S1 disc is about 18mm (7-36mm) \(^{(14)}\). The space for approaching this level is restricted by the left common iliac vein and the right common iliac artery, and this distance is on average 33.5mm (12-50 mm). Because of these limited distances it could be necessary to dissect up to the left common iliac vein which crosses to the disc where it is only on average 12mm left of the midline.

For L5-S1 levels in most of the patients this dissection is sufficient to reach the disc space. This is shown in 90% of the patients by Capellades in his MRI based study \(^{(11)}\). Median sacral vessels are always coagulated before the mobilization of the aorto caval bifurcation and iliac vessels. On the other hand, it should be kept in mind that median sacral vessels are not denoted to midline.

If there is not an adequate amount of space between the iliac vessels for L5-S1 level approach, common iliac veins and arteries should be dissected and hung up with vascular tapes. The com-

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**Figure 2:**
In situation - Line A – L4-L5 level is above the bifurcations. Either both aorta and vena cava have to be retracted to the right side (figure 2a) or – as shown in figure 2b- aorta and vena cava are pulled laterally away from each other \(^{(15)}\).
The superior hypogastric plexus, contains the sympathetic function for the urogenital system, is situated in front of the last lumbar vertebra and the promontory of the sacrum, between the iliac vessels. Cleavage of this area is carried out by blunt dissection, electrocautery or traumatic surgery may cause retrograde ejaculation in male patients. Separation of the probable nerve fibers is carried out in a cranio-caudal direction and transverse cuts are avoided in prevertebral tissue. After the dissection is completed and the disc is exposed clearly a self-retaining device is put in place by three pins and spinal surgery begins.

Some of these challenges are originated from the directions of skin incisions. For a single level disease it is logical to make a transverse incision for extraperitoneal approach which permits well exposition for the left side of the extraperitoneal space while it can not be mentioned for contralateral side. Also, transverse incisions give better cosmetic results. Vertical midline incision is superior with its extensibility for the two level diseases. For repairing the vascular injuries, vascular surgery instruments are kept ready to use in the operating room. It is helpful to determine the relationship of vessels and disc level before the surgery by CT scan or MRI.

4.d. Ventrolateral Approach to L4-S1
The patient is positioned in supine and there is no need for special arrangement. A horizontal left paramedian skin incision of about 4cm is placed over the disc level, which is determined by C-arm, and 1-2cm lateral to the midline. This incision is suitable for single level interventions. After the opening of anterior rectus sheath, cutting starts from the most lateral part of the muscle by electrocautery. Inferior epigastric vessels and branches should be ligated or coagulated carefully to avoid hematoma. Like skin incision severing of 1-2cm medial part of the muscle is not required. The most lateral part of the posterior sheath is the safest area to avoid to open the peritoneum and to enter preperitoneal.
space, because all the fascial layers fuse through the midline, and peritoneum becomes closer to them. After identification of peritoneum lying under the transversalis fascia at the lateral border, the posterior sheath, including fascia transversalis, is cut to 1-2cm to medial part, as done at the skin and at the muscle. After the opening of posterior rectus sheath, finger dissection begins within the preperitoneal tissue that is bordered peritoneum internally and fascia transversalis externally. Through this finger dissection first protrusion is felt at the posterior wall is psoas muscle.

Identification of the ureter is not required while its location is lateral and not close to surgical field. Although identification of ureter is thought as an obligation by many surgeons during the separation of peritoneum from the preperitoneal fat ureter is left in this fatty tissue. During finger dissection, peritoneum cannot be mobilized at the inferolateral corner because of the internal inguinal ring, which serves as the lower border of the dissection. For the cranial side, 5-6cm freeing of peritoneum is sufficient to move the peritoneal sac medially. Medial retraction of the peritoneal sac reveals the great vessels and dissection proceeds under direct visualization. Aorta, vena cava and their bifurcations identified first by bluntly sweeping off the fatty tissue surrounding them. Vessels should be kept away from the field to avoid injury. For the lateral discectomy and disc prosthesis placement extensive anterior dissection is not required. For anterior discectomy or vertebrectomy vessels are dissected and pulled away from the surgical field (Figure 5).

We do not prefer the self retraining retractors for this approach. After the spinal instrumentation is completed, sutures between the layers are cut and posterior peritoneum is closed by continuous fashion, then anterior wall is closed as a single layer. No drainage is used in the postoperative period. Narcotic analgesics may affect food tolerance otherwise normal diet is given the same day. Early ambulation is recommended.

4.e. Open Window Laparotomy for Approach to L4-S1

Open window laparotomy reduces the risks of vascular and abdominal organ injuries, provides better exposure of the anterior portion of the vertebra and retraction advantages. This method is based on the philosophy of protection of the abdominal organs, facilitation of retraction, simplification of the retroperitoneal approach and for direct access to retroperitoneum by anterior access.

A midline approach is also preferred for patients who had previous abdominal, especially pelvic, and patients with relative contraindications for minimal invasive anterior approaches such as for obese patients, for complicated cases such as patients previously operated on these levels either by the posterior or anterior approaches or for recurrent cases. Vascular dissection in this approach is simpler because dissection of the right iliac vessels is easier than in the extraperitoneal approach performed by transverse left transrectal incision (Figure 6). A 4cm vertical midline skin incision is made over the lesion site where identified by C-arm fluoroscope. For slim patients, palpation of the sacral promontory and incision according to its projection will be adequate. It should be remembered that incision reveals the disc space by right angle.
After the exploration of the peritoneal cavity, small intestine is shifted right and sigmoid colon left. Then, posterior parietal peritoneum is hanged up between the clamps and opened in the same direction with skin but larger, approximately 6-8cm, and peritoneal flaps are freed with finger dissection in each direction. The free lips of the posterior peritoneum are sutured to anterior parietal peritoneum and linea alba with 00 monofilament 8 shaped sutures spaced 1cm apart. An important point is starting to sew from the superior corner then through the inferior corner because injury of intestinal loops is greatest in this site. As its trace is completely out of the surgical field we don’t pay special attention to identifying the ureter. After the window is completed, vascular dissection starts. Resuming normal diet may take longer than with extraperitoneal access. But oral fluids can be started at the same day.

4.f. Laparoscopic Lumbar Surgery

Patient is positioned supine, 30 degrees trandelenburg and legs are open. Surgeon works between the legs and the assistant on the one side of the patient. Monitor is on the opposite side beyond the shoulder of the patient (Figure 2 in chapter 5H). Laparoscopic approach can be performed by three 10mm trocars, the suprapubic trocar may be changed with a larger like 12 or 18mm. First one is placed midline at suprapubic region. It is, essentially, used for 0 degree camera. Other two ports are working trocars and are inserted on both side of the midline, lateral to the inferior epigastric vessels, again between the pubis and umbilicus but more cranial than camera port for easily emptying intervertebral space. Determination of the trocar sites requires laparoscopic experience because all the ports must target the intervertebral space with correct angles. Three 10mm or larger trocars give us flexibility of using them in a changing manner as camera and working ports during operation. Although many surgeons prefer 0 degree camera, we mostly use 45 degrees which gives a better exposure at deep of the intervertebral space.

After the insertion of the first trocar with open technique pneumoperitoneum is accomplished then other two trocars are inserted. Sigmoid colon is pushed to patient’s left and small intestines are right upward from the mesentery to reach the peritoneum on the vertebral colon. Trandelenburg position allows to small intestine fall cranial.

First, bifurcations are identified. Ureters are lying laterally than surgical field and generally there is no need to expose them. Peritoneum is cut by a scissors in vertical axis while it is hanged by a grasper to prevent an injury of underlying vessels. After sweep-
ing off the retroperitoneal fat disc and median sacral vessels lying on the anterior surface of the vertebra are identified. Median sacral vessels are isolated and coagulated by a bipolar electrocautery or by clips then cut by an endoscopic scissors. During retroperitoneal dissection sharp dissections and electrocautery usage, especially monopolar electrocautery, may cause retrograde ejaculation due to superior hypogastric plexus injury. There is no extensive vascular mobilization requirement for the L5-S1 level. The only need is to be clearly identified borders of disc and vascular structures.

5. References: