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ORIGINAL ARTICLE

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The ALIF concept

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Abstract The terms 'minimally invasive' or 'less invasive surgery' have been used recently to describe surgical approaches or operations that are performed with less trauma to anatomical structures on the way to or surrounding the surgical 'target area'. These types of surgical procedures are usually performed with the help of 'high-tech' instruments such as surgical endoscopes or surgical microscopes, modern video techniques and automated instruments. Within the last 10 years, such techniques have been developed in the field of spinal surgery. The application of minimally or less invasive procedures has concentrated predominantly on anterior approaches to the thoracic and lumbar spine. This article describes two anterior approach techniques for performing anterior lumbar interbody fusion (ALIF) through a minimally invasive retroperitoneal or transperitoneal approach. The technical principles are microsurgical modifications of traditional anterior approaches to the lumbar spine. Through small (4-cm) skin incisions, the target area can be exposed. Preliminary results suggest decreased peri - and postoperative morbidity, less blood loss, earlier rehabilitation and acceptable complication rates. The technique is currently used by the author for all patients requiring anterior lumbar interbody fusion.

Key words Microsurgery · Lumbar spine · Mini ALIF · Anterior lumbar interbody fusion

Introduction

The development of new techniques to approach surgical targets of the anterior thoracic and lumbar spine has been one of the major challenges in spine surgery within the last 10 years. Since the first description of laparoscopic discectomy in 1991, tremendous progress has been made towards minimizing iatrogenic trauma during the surgical approach [14, 20, 25]. A variety of terms such as 'minimally invasive', 'less invasive' or even 'adequate invasive' surgery has been used in the literature to describe the different surgical philosophies that follow these principles. Being most efficient and least invasive has always been the main goal of any surgical intervention in the lumbar spine. This must always be kept in mind when discussing minimally invasive *approaches*, which does not necessarily imply minimally invasive surgery in the target area.

Although good results with anterior interbody fusion techniques have been reported recently [9, 10, 12, 13], iatrogenic trauma has always been the main argument against anterior approaches to the lumbar spine [2–9, 23, 24]. This is one of the reasons, why most of the efforts have been directed at facilitating anterior interbody fusion techniques.

Two main surgical philosophies for anterior approaches to the lumbar spine have resulted from these scientific efforts: 'closed' endoscopic ('laparoscopic') approaches and so-called minimally 'open' approaches, which are microsurgical or 'open' endoscopic modifications of conventional approaches. The characteristics of the latter include

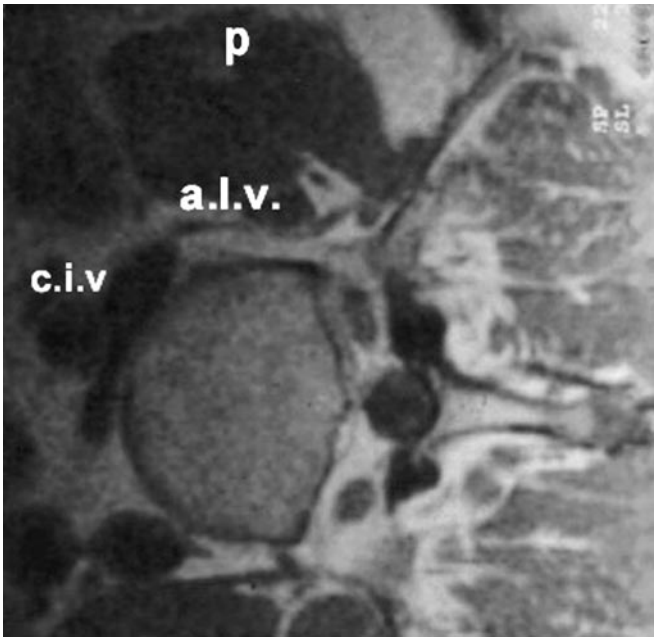


Fig. 1 Magnetic resonance (MR) image of the lumbar spine for preoperative planning: motion segment L4/5. Note the common iliac vein as well as the course of the ascending lumbar vein. (*p* psoas muscle, *c.i.v.* common iliac vein left side, *a.l.v.* ascending lumbar vein)

the use of frame-type retractors, which open a surgical corridor to the target area [15–17, 21].

This article describes the principles of the retroperitoneal and transperitoneal mini-open route to perform anterior lumbar interbody fusion.

General principles

The two approach techniques presented in this article have several principles in common:

1. They are modifications of the conventional retroperitoneal and transperitoneal approaches described in the literature [1, 11].
2. Surgical dissection follows preformed anatomical clefts and spaces.
3. Preservation of the integrity of soft tissues is paramount.
4. They are performed with the help of optical aids (surgical microscope or endoscope).
5. The surgical corridor is maintained with frame-type retractors.
6. All surgeries can be performed with the help of one assistant.
7. Several types of interbody fusion are possible (e.g., autograft, allograft, etc.).

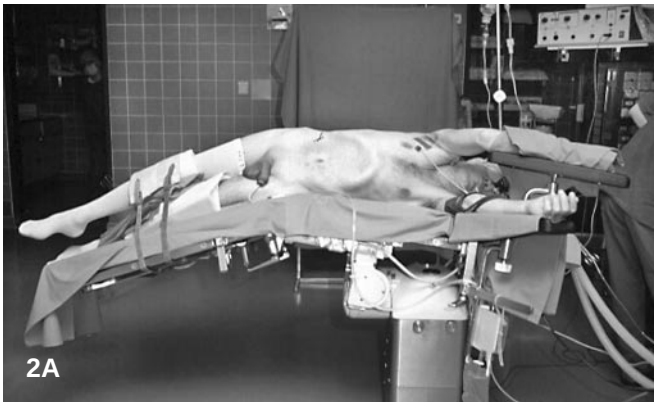


Fig. 2 A, B Positioning of the patient for retroperitoneal anterior microsurgical approach. **A** View from anterior: table is tilted to 'open' the distance between iliac crest and rib cage **B** View from the side: table is tilted backwards between 20˚ and 40˚ to facilitate the approach medial to the psoas muscle as well as the identification of the lateral borders of the anterior longitudinal ligament

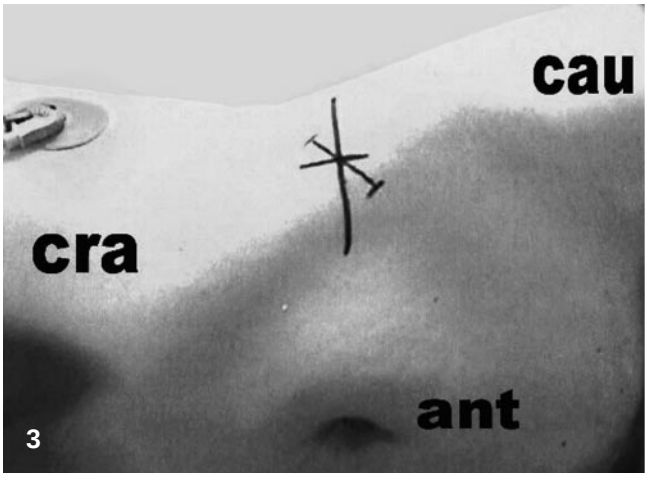


Fig. 3 Skin incision centered over the target point (*left* = caudad, *right* = craniad, *top* = anterior)

8. All approaches and fusion techniques are described as part of a 270° fusion philosophy, which includes posterior stabilization (e.g., pedicle screws, translaminar screws) [10].

Preoperative planning and preparation of the patient

The topographical anatomy of the anterolateral circumference of the target segment must be studied preoperatively. In addition to information about the underlying pathology, magnetic resonance imaging (MRI) of the lumbar spine and its surrounding structures gives all the anatomical information that is for meticulous preoperative planning (Fig. 1).

Preoperative conventional radiographs of the lumbar spine in two planes are mandatory in order to get enough information on the spine curvature, the height of the intervertebral space, the orientation of the disc space (L5/S1) and the sacral inclination. The level of the bifurcation of the aorta and vena cava must be determined preoperatively for the approach to L5/S1 This can be achieved in the majority of the patients with conventional MRI. MRI angiography can be helpful in uncertain cases. For the transperitoneal L5/S1 approach, abduction of the hip joints should be checked preoperativelyPatients are treated with routine mechanical large-bowel preparations as well as purgatives starting 24 h before the operation.

Anesthesia

The operation is performed under general anesthesia. Once the patient is anesthetized, a Foley catheter and a nasogastric tube are inserted. Arterial and central venous pressure lines are placed because hemodynamic monitoring is important. We recommend 500 cc own-blood donation before the operation.

Positioning and localization

Retroperitoneal approach (L2–L 5) (Fig. 2)

The operation is performed with the patient in a right lateral decubitus position on an adjustable surgical table. The table is tilted to increase the distance between the iliac crest and the inferior border of the rib cage (Fig. 2 A). According to the level to be approached, the table is then tilted backwards in the axial plane for 20° degrees (L4/5), 30° (L3/4) or 40° (L2/3) (Fig. 2 B). The orientation of the lumbar motion segment is then checked with lateral fluoroscopy. The orientation of the disc level (‘orientation line’) as well as the center of the disc space (‘center line’) are marked onto the skin level. The line of the skin incision is centered over the target point (intersection of the orientation and the center line) in an oblique direction (parallel to the fiber orientation of the external oblique abdominal muscle) (Fig. 3).

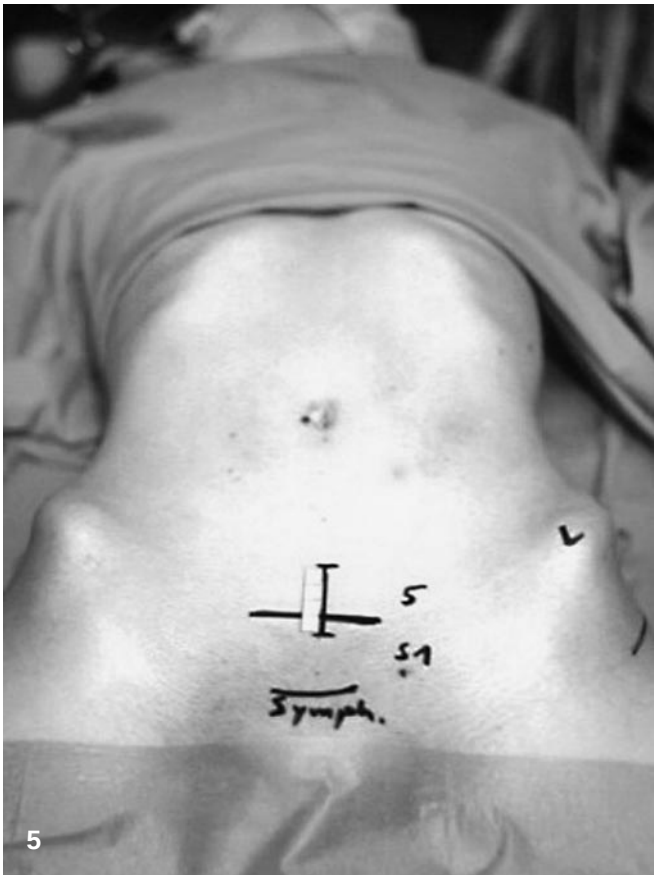
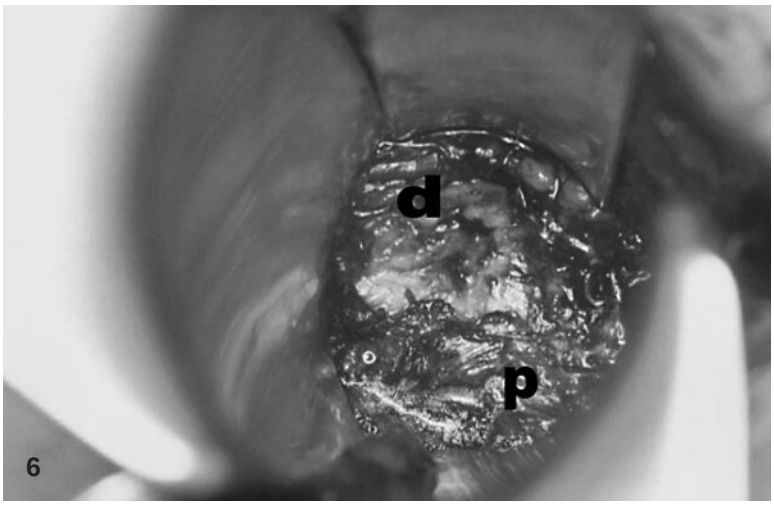


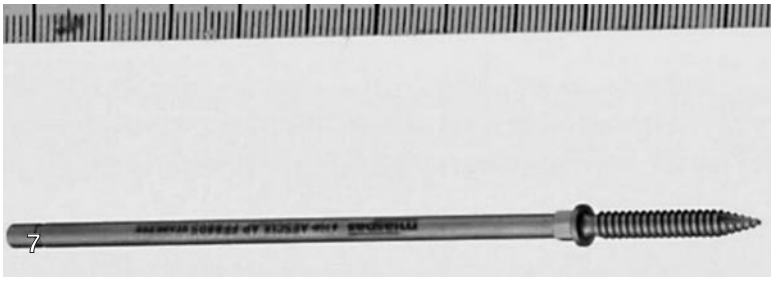
Fig. 4 Positioning of the patient for transperitoneal anterior approach to L5/S1

Fig. 5 Corridor line and skin incision marked on the midline

Transperitoneal approach L5/S1

The patient is placed in a supine Trendelenburg position (trunk tilted 20°–30°), with the lumbar spine hyperex-





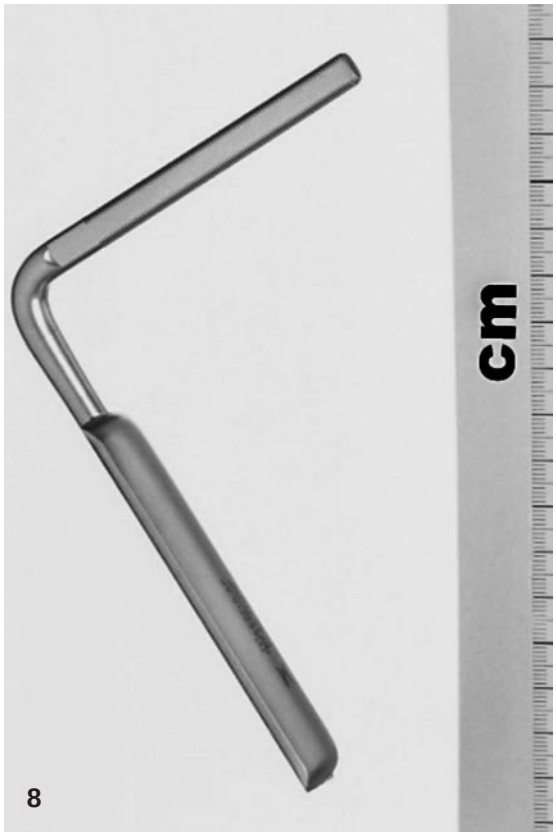


Fig. 6 Exposure of the anterolateral circumference of disc space (*d* intervertebral disc, *p* psoas muscle

Fig. 7 Anchoring screw (self-tapping)

Fig. 8 Soft tissue blade for retraction of the soft tissue cranial and caudal to the intervertebral space

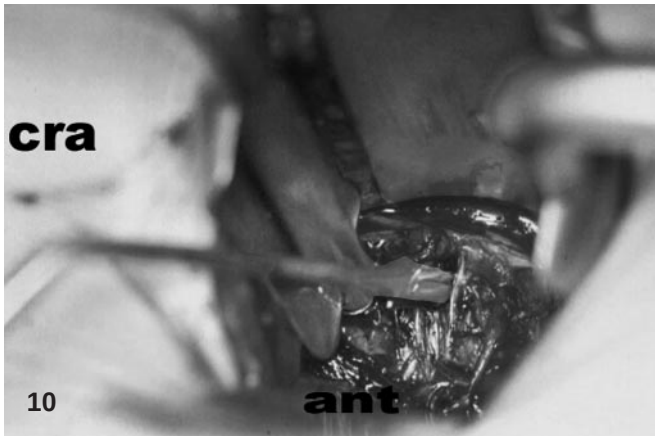
Fig. 9 Self-retaining frame retractor

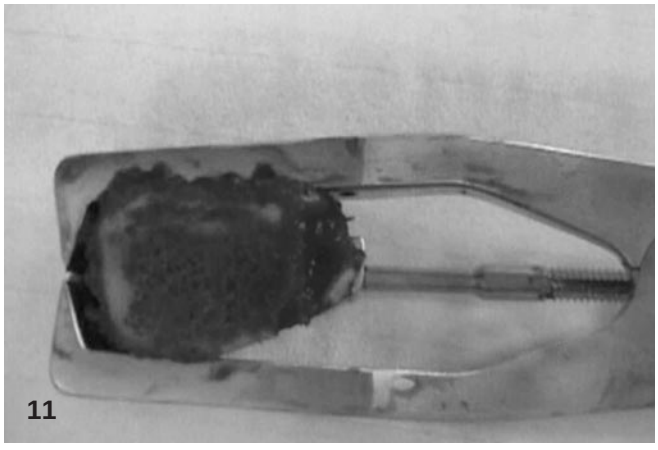
tended and legs in maximum abduction (Fig. 4). The position of the surgeon is between the legs of the patient. The orientation of the L5/S1 disc space is marked as it projects onto the skin in a lateral fluoroscopic view ('disc line'). The anterior border (tangent) of the promontorium is also marked onto the skin ('border line'). The intersection of both lines is usually located at the lateral part of the patient's buttock cranial to the major trochanter. A transverse line is drawn from this intersection point onto the abdomen ('corridor line') (Fig. 5). This corridor line is located in the middle third of the distance between umbilicus and symphysis. A 4-cm skin incision is centered over this line strictly in the midline ('incision line').

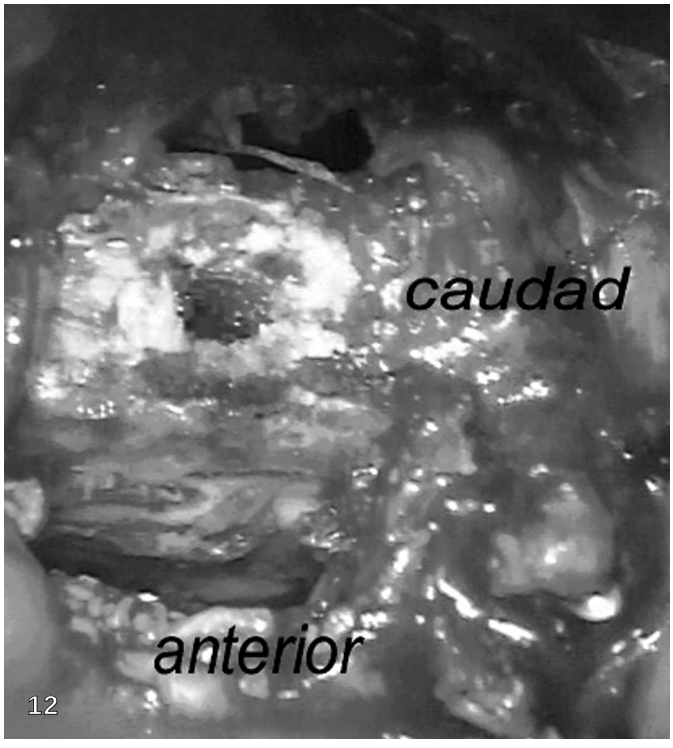
Surgical steps

The retroperitoneal approach to L2–L5

A 4-cm skin incision is sufficient for the exposure of one segment. The retroperitoneal space is exposed through a blunt, muscle splitting approach. Blunt dissection is continued in the retroperitoneal space to expose the anterior and







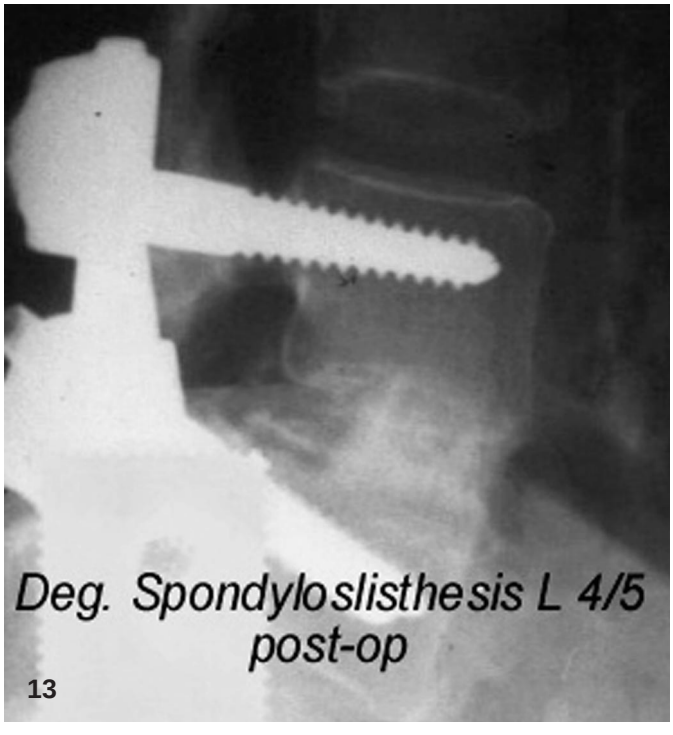


Fig. 10 Surgical field after placement of the frame retractor (*ant* anterior, *cra* craniad)

Fig. 11 Graft cutter with bone graft removed from the iliac crest

Fig. 12 Graft impacted into the intervertebral space

Fig. 13 Lateral postoperative radiograph shows bone graft in place at L4/5. Note posterior instrumentation

medial circumference of the psoas muscle. The operation is now continued with the help of the surgical microscope (focus depth 350 mm). Anteromedial attachments of the psoas muscle are sharply dissected between 1 and 1.5 cm from the anterolateral circumference of the disc space. At L4/5, the common iliac vein may cover the mediolateral aspect of the intervertebral space. The vein can be gently retracted after mobilization in the majority of cases. The lateral border of the anterior longitudinal ligament is now visible and blunt dissection is completed when 5°–10 mm of the adjacent vertebral bodies are exposed (Fig. 6).

The disc space level is verified under fluoroscopic control, and the self-tapping anchoring screws are inserted (Fig. 7). These screws hold the cranial and caudal spreader valves (Fig. 8).

A self-retaining frame-type retractor is attached to the blades (Fig. 9). The anterolateral circumference of the segment to be fused is now exposed (Fig. 10). After removal of the disc and cartilagenous endplates, anterior lumbar interbody fusion is performed, usually with an autologous iliac bone graft. However, other types of anterior interbody fusion, including the use of homografts, have been reported.

A tricortical iliac bone graft is harvested through a separate small incision over the lateral iliac crest on the same side. If L4/5 is approached, the graft can be harvested before exposure of the disc space through the same skin incision (Fig. 11). The graft is mounted onto a graft holder and impacted into the intervertebral space (Figs. 12, 13).

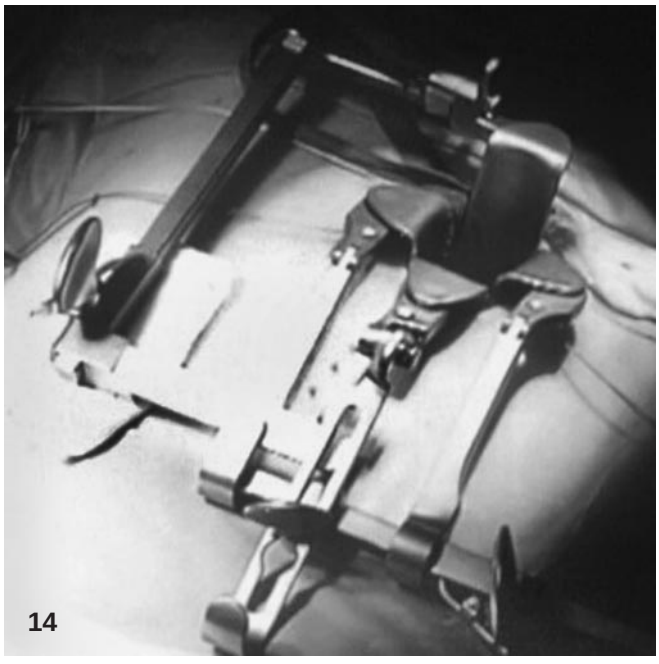
Surgical steps

The transperitoneal approach to L5/S1

A 4-cm skin incision is placed in the midline centered over the 'corridor line'. The rectus fascia is opened along the linea alba. A soft tissue spreader with blunt blades is then inserted to retract both rectus muscles from the midline. The peritoneum is then opened and armed with four sutures placed at the craniad and caudad edges. The mesenterium with the ileum is carefully pushed into the upper left abdominal cavity, using Langenbeck hooks for blunt dissection and small abdominal towels to hold the abdominal contents in place. The same is done to the colon sigmoideum, which is carefully retracted to the left. A soft tissue retractor with blunt blades is inserted to retract the bowel to the right and to the left after identification of the common iliac artery and the retroperitoneal course of the urether on the right side. The retractor is now completed with two other blades to expose a working corridor to the anterior circumference of L5/S1 (Fig. 14).

The incision of the prevertebral peritoneum is made about 15 mm medial to the right common iliac artery, and completed in a semicircular manner in order to avoid damage to the superior hypogastric plexus. Dissection is performed bluntly, only bipolar coagulation is allowed. Thus, the anterior circumference of L5/S1 as well as the median sacral vessels (a.v. sacralis mediana) are exposed. The vessels are closed with vascular clips, dissected and retracted from the disc surface.

The anterior longitudinal ligament and the anulus fibrosis are incised in a rectangular shape, the disc is removed, and interbody grafting is performed. The orientation of the graft is strictly along the midline in parallel to the sagittal plane (Fig. 15).



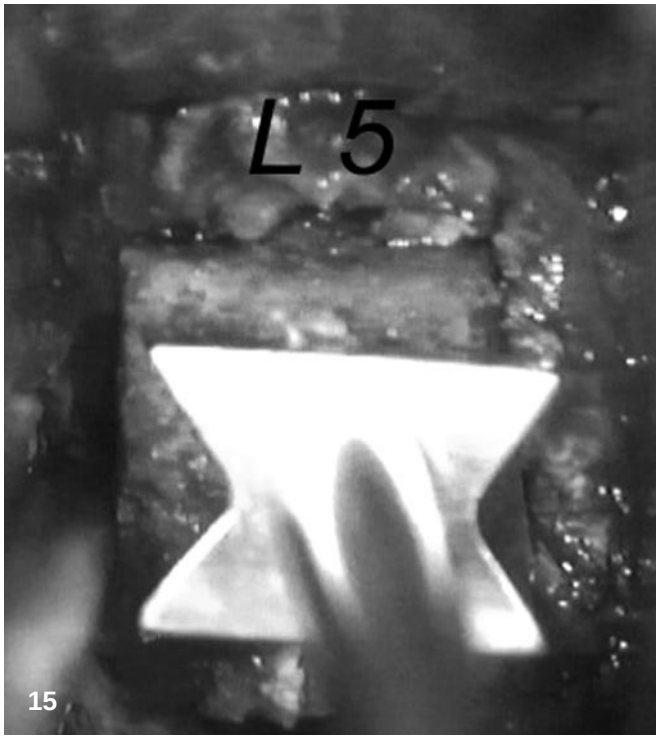


Fig. 14 Exposure of the promontorium by the soft tissue retractor

Fig. 15 Intraoperative view of bone graft in place at L5-/S-1

Indications

The approaches have been used for anterior lumbar interbody fusion in the following diseases (in the majority of ourown cases combined with posterior instrumentation):

1. Degenerative instability (mainly with Modic Type I changes on MRI) [19]
2. Degenerative spondylolisthesis
3. Isthmic spondylolisthesis
4. Spinal stenosis with instability
5. Failed back surgery syndrome
6. Fractures
7. Spondylitis/spondylodiscitis
8. Pseudoarthrosis following other types of fusion (e.g.,posterolateral, PLIF)

Contraindications

The following situations should each be considered as absolute contraindications to a retro- or transperitoneal approach:

1. Previous major abdominal or gynecological surgery through a retroperitoneal or transperitoneal route (e.g., hysterectomy; colon resection, etc.)
2. Low vascular bifurcation (in front of L5/S1)

Relative contraindications are considered to be:

1. Spondylitis/spondylodiscitis with large prevertebral soft tissue mass or psoas abscess
2. Previous anterior interbody fusion at the same level
3. Previous minor abdominal surgery (e.g., appendectomy, laparoscopic surgery)
4. Abdominal diseases (e.g., Crohn's disease; colitis ulcerosa, etc.)
5. Adipositas permagna
6. Extremely lateral course of common iliac vein of the left side covering the lateral aspect of the L4/5 intervertebral space

Results and complications

Retroperitoneal approach L2–L5

Microsurgical anterior lumbar interbody fusion has been performed in 120 patients:66 female, 54 male; age range 26–84 years (mean 56.3 years). All the procedures were performed as part of a 270˚ fusion philosophy, which includes posterior instrumentation (with/without decompression of the spinal canal) with pedicle screw systems or translaminar screws and arthrodesis of the facet joints, combined with anterior lumbar interbody fusion. The average duration of surgery was 102.2 min. This average includes 16 double-level cases as well as all cases performed early in the learning curve. Duration of surgery ranged from 50 to 195 min. Average blood loss was 139.8 cc (67.3 cc at the fusion site, 78.1 cc at the graft donor site). None of the patients received any blood transfusion for the anterior approach. Preoperative evaluation of the economic and functional status of the patients was performed with the help of the EFR score, published by Prolo in 1986 [22]. All patients were rated 'poor' preoperatively. After an average follow-up period of 24 months, 62% of the patients showed excellent or good clinical results; 23% were satisfactory and 15% had poor results. The patients were asked to give a self-rating of the result of surgery. A total of 73% were either completely satisfied or reported a significant improvement of their symptoms . Nineteen percent of the patients reported unchanged symptoms and 8% stated that their symptoms had become worse after the surgery.

We observed a total of 16 complications (13.3%). Five of them were donor-site complications. There was one general complication (deep venous thrombosis) as well as three complications from the posterior approach (pedicle fracture, implant loosening, loss of correction). There were seven complications specific to the anterior approach: four pseudarthroses and three cases of irritation of the genitofemoral nerve.

Transperitoneal approach L5/S1

Microsurgical transperitoneal anterior lumbar interbody fusion has been performed in 51 patients: 27 female, 24 male; age range 10–68 years (mean 44.1 years). All the procedures were performed as part of a 270° fusion philosophy, which includes posterior instrumentation (with/without decompression of the spinal canal) with pedicle screw systems or translaminar screws and arthrodesis of the facet joints (except in isthmic type spondylolisthesis), combined with anterior lumbar interbody fusion. The average duration of surgery was 122.5 min,. ranging from 65 to 205 min. Average blood loss was 78.9 cc at the fusion site and 77.5 cc at the donor site for the bone graft . None of the patients received any blood transfusion for the anterior approach.

Preoperative evaluation of the economic and functional status of the patients was performed [29]. Forty-five of the patients (89%) had a poor score preoperatively. After an average follow-up period of 20 months, 94% of the patients showed excellent or good clinical results, 6% were satisfactory and none of the patients had a poor result. The patients were asked to give a self-rating of the results of surgery. All the patients were completely satisfied with the operation.

We had a total of 8 complications in 51 operations (15.1%). However, only one of these was specific to the approach (1.96%). A 15-year-old boy with an isthmic type spondylolisthesis suffered from an ileus on the 5th postoperative day after microsurgical anterior interbody fusion at L5/S1. However, this boy had Crohn's disease, which may have contributed to this postoperative complication. All other complications were either due to the posterior instrumentation (loosening of implant $n = 1$; fracture of the pedicle during insertion of pedicle screw $n = 1$)

or due to the harvesting of the bone graft (fracture of the ileum $n = 1$; hematoma at the donor site $n = 2$; superficial wound infection at the donor site $n = 1$). One patient had a postoperative laryngeal irritation due to intubation.

Critical evaluation

The approaches described in this article are microsurgical modifications of well-known conventional anterior approaches to the lumbar spine. They have been standardized as far as possible and microsurgical principles have been applied to the development of instruments as well as to the surgical technique. Positionings of the patient have been modified to facilitate surgical dissection. This has the advantage that the lumbar spine can be reached through a 4-cm incision even in obese patients. The lateral retroperitoneal approach can, however, be disadvantageous in patients with a wide pelvis or a high iliac crest, since these anatomical variations create an increased distance between the skin levels and the target area on the lumbar spine.

The retractors make it possible to perform the operations with only one assistant. In the author's experience, it is easier to handle the retroperitoneal blood vessels (common iliac vein, segmental vessels, ascending lumbar vein), or the prevertebral soft tissues at L5/S1, when a microscope is used. The risk of direct injury to the structures at risk is minimized.

Crossing the abdominal cavity carries certain risks for the anatomical structures that are located on the way to the promontorium. The bowels must be handled very gently, using only blunt instruments and hooks for preparation [18].

In patients with a history of abdominal surgery, mobilization of the bowel must be performed very cautiously. Since only the small surgical corridor is visible through the microscope, there is a potential risk for indirect damage to the bowel due to forceful retraction.

There are several disadvantages associated with these minimally invasive approach techniques:

1. Due to the standardization of the surgical steps and the size of the approach, a maximum of two levels can be approached through one skin incision.
2. Spatial orientation in the target area is strongly dependent on the exact positioning of the patient.
3. The majority of complications occurred during the posterior instrumentation and not during anterior surgery.
4. A considerable number of complications related to the donor site, raising questions of alternatives to solid iliac bone grafts (e.g., vertical cages, spacers).

In our opinion, the major advantages of the techniques turned out to be:

1. Reproducible techniques with a short learning curve
2. Low peri- and postoperative morbidity, including negligible intraoperative blood loss
3. The possibility of early mobilization and rehabilitation due to the preservation of the functional integrity of the abdominal wall
4. Good clinical results (at least as good as with conventional techniques)
5. Ancceptable complication rate
6. Well accepted by the patients themselves
7. A variety options for type of interbody fusion: autogenous iliac bone graft; augmented horizontal and vertical cages; homogeneous bone grafts (bank bone), etc. [13].

References

1. Bauer R, Kerschbaumer F, Poisel S (eds) (1992) Orthopädische Operationslehre.I. Wirbelsäule. Thieme, New York Stuttgart
2. Bohlman HH, Eismont FJ (1981) Surgical techniques of anterior decompression and fusion for spinal cord injuries. Clin Orthop 154:57–67
3. Capener N (1932) Spondylolisthesis. Br J Surg 19:374–386
4. Crock HV (1982) Anterior lumbar interbody fusion. Clin Orthop 165:157–163
5. Faciszewski T, Winter RB, Lonstein JE, Denis F, Johnson L.(1995) The surgical and medical perioperative complications of anterior spinal fusion surgery in the thoracic and lumbar spine in adults. Spine 20:1592–1599
6. Fujimaki A, Crock HV, Bedbrook GM (1982) The result of 150 anterior lumbar interbody fusion operations performed by two surgeons in Australia. Clin Orthop 165:164–167
7. Gertzbein SD, Court-Brown CM, Jacobs RR, et al. (1988) Decompression and circumferential stabilization of unstable spinal fractures. Spine 13:892–895
8. Greenough CG, Taylor LJ, Fraser RD (1994): Anterior lumbar fusion. A comparison of oncompensation patients with compensation patients. Clin Orthop 300:30–37
9. Greenough CG, Taylor LJ, Fraser RD (1994) Anterior lumbar fusion: results, assessment techniques and prognostic factors. Eur Spine J 3:225–230
10. Grob D, Scheier HJG, Dvorak J, Siegrist H, Rubeli M, Joller R. (1991) Circumferential fusion of the lumbar and lumbosacral spine. Arch Orthop Trauma Surg 111:20–25
11. Harmon PH (1963) Anterior excision and vertebral body fusion operation for intervertebral disc syndromes of the lower lumbar spine. Clin Orthop 25:107–127
13. Kozak JA, Heilman AE, O'Brien JP (1994) Anterior lumbar fusion options. Clin Orthop 300:45–51
14. Mathews HH, Evans MT, Molligan HJ, Long BH (1995) Laparoscopic discectomy with anterior lumbar interbody fusion. Spine 20:1797–1802

15. Mayer HM (1997) A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine 22:691–700
16. Mayer HM (1998) Microsurgical anterior approaches for anterior interbody fusion of the lumbar spine. In: McCulloch JA, Young PH (eds.). Essentials of spinal microsurgery. Lippincott-Raven, New York Philadelphia, pp 633–649
17. Mayer HM (ed) (2000) Minimal invasive spine surgery. Springer, Berlin Heidelberg New York (in press)
18. McAffee PC, Regan JR, Zdeblick T, et al (1995) The indicidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery. Spine 20:1623–1632
19. Modic MT, Steinberg PM, Ross JS, et al (1988) Degenerative disk disease: assessment of changes in vertebral body marrow with MR tomography. Radiology 166:193–199
20. Obenchain TG (1991) Laparoscopic lumbar discectomy. J Laparoendosc Surg 3:145–149
21. Onimus M, Chataigner H (2000) The anterior extraperitoneal pararectal video-assisted approach to the lumbar spine. In: Mayer HM (ed) Minimal invasive spine surgery. Springer, Berlin Heidelberg New York (in press)
22. Prolo DJ, Oklund M, Butcher M (1986) Toward uniformity in evaluating results of lumbar spine operations. Spine 11:601–606
23. Spivak JM, Neuwirth MG, Giordano CP, Bloom N (1994): The perioperative course of combined anterior and posterior spinal fusion. Spine 19:520–525
24. Stauffer RN, Coventry MB (1972) Anterior interbody lumbar spine fusion. J Bone Joint Surg Am 54:756–768
25. Zucherman JF, Zdeblick TA, Bailey SA, Mahvi D, Hsu KY, Kohrs D (1995): Instrumented laparoscopic spinal fusion. Spine 20:2029–2035