

Laparoscopic Anterior Lumbar Interbody Fusion with a Single, Large, Lordotic Cage, a Case Series

V. Lykomitros¹, D. Moschos², A. Gerakis¹, D. Apostolidis³, J. Liveris⁴, I. Polythodorakis⁴

¹*Euromedica Geniki Clinic of Thessaloniki, Greece*

²*Orthopaedic Department, Hippocraton General Hospital, Thessaloniki, Greece*

³*Surgical Department, 424 General Military Hospital, Thessaloniki, Greece*

⁴*Hygeia Hospital, Athens, Greece*

ABSTRACT

AIM: The aim of this paper is to present our experience with laparoscopic anterior lumbar fusion and to demonstrate the technique with a single, large, lordotic cage, as a new and innovative method for 360- or 540-degree interbody fusions for demanding L5-S1 fusion cases.

MATERIAL AND METHODS: Twelve patients underwent laparoscopic ALIF between October 2010 and May 2013. Mean patient age was 49 years. Patient inclusion criteria were chronic degenerative disc disease, spondylolisthesis, trauma and failure of previous posterior fusion. In the spondylolisthesis and the revision cases, a 540-degree fusion was done, the first part of which was either an extended laminectomy and facetectomy or instrumentation removal with the patient in the prone position. The next part of the procedure undertaken in all patients was the laparoscopic placement of a single ALIF type cage in the L5-S1 and in one case in the L4-L5 intervertebral space, and the final part of the operation, completing either a 360 or a 540 degree fusion, was the posterior instrumentation implantation with graft placement. Mean operative time was 270 min.

RESULTS: Early, full mobilization was commenced in all patients. No major complication occurred during or after the surgery and within one year, solid fusion was documented in all twelve patients. A significant improvement in visual analogue scale score and Oswestry disability index was documented in all patients.

CONCLUSIONS: Laparoscopic lumbar interbody fusion when performed with a single, large, lordotic ALIF type cage, is an innovative technique, that in our experience led to excellent results, particularly in the demanding L5-S1 fusion cases and proved to be safe and comparable with the open fusion techniques.

KEY WORDS: ALIF, Fusion, LALIF, Laparoscopic, Lumbar, 540 degrees

INTRODUCTION

Anterior lumbar interbody fusion (ALIF) is a procedure originally described by Carpener in 1932 for the treatment of spondylolisthesis (3) and a few years later it was popularized by Freebody et al. (11). Since then, it has been described and performed for a variety of pathologic conditions apart from spondylolisthesis, including symptomatic degenerative disc disease and as a salvage procedure for failed posterior spinal fusion (9). The anterior approach to lumbar fusion has significant advantages over the posterior, including avoidance of

paraspinal musculature damage and partial denervation, avoidance of epidural scarring, less risk related to nerve retraction, the ability to perform a more complete disc excision and place a larger interbody fusion device and the shortening of hospitalization time (14,29,36). On the other hand, the approach is associated with certain complications due to the vicinity of the surgical field with the iliac veins and the superior hypogastric plexus, mainly vascular injuries and retrograde ejaculation (12, 32).

The initial procedure was performed through the transperitoneal approach, but this was later substituted

with the retroperitoneal approach after its description from Iwahara in 1944 (19) mainly due to the significant less likelihood of retrograde ejaculation with this approach (30). Although the safety of the anterior approaches to the lumbar spine was established in the 1970s and 1980s, its efficacy as a stand-alone procedure was not, due to the low fusion rates reported with the technique and the limited access of the approach to the posterior space for the treatment of nerve compression. Following a 1972 clinical study authored by Stauffer and Coventry (31) that definitively demonstrated the low fusion rates of ALIF without instrumentation, a combination of anterior with posterior fusion became common (25). The anterior approach was utilized for the discectomy, the restoration of the lumbar lordosis and the fusion cage insertion while the posterior approach for instrumentation and stabilization.

Recently, the modern laparoscopic surgical technique was combined with the ALIF procedure in an effort to minimize surgical trauma resulting from the extended standard anterior approaches, while at the same time reducing bowel irritation and post-operative ileus. Obenchain was the first to publish in 1991 a case report describing a laparoscopic approach to the lumbar spine for discectomy, which led to the first series of laparoscopic ALIF (LALIF) procedures with threaded interbody cages, reported by Zucherman et al in 1995 (37). The following years, many more publications surfaced evaluating the new technique. Among them, notable is the prospective multi-centre study by Mc Afee et al, that demonstrated the safety and efficacy of the procedure.

The interbody devices utilized in the ALIF procedure also underwent a significant evolution. Ralph Cloward introduced in 1953 the dowel technique that involved the use of cylindrical corticocancellous dowels (6) and Harmon was the first to utilize the bone dowel technique for an anterior lumbar fusion (15). Holte et al developed in 1994 a hybrid interbody graft by using a femoral allograft ring as a fusion cage for acute stability, filled with autogenous cancellous bone graft in order to achieve fusion and long term stability (16). The next evolutionary step of the technique was the substitution of the allograft cage for a cylindrical titanium threaded cage (BAK, Spine-Tech) which was screwed into the end plates (26). Early satisfactory results have been reported using this type of cage (28). A similar device developed by Ray (Ray TFC, Surgical Dynamics) was also utilized in the ALIF procedure.

The last generation implant was the lordotic lumbar tapered (LT) cage (Medtronic) which provided several advantages over the cylindrical devices (35). It enabled the surgeons to better restore lumbar lordosis by symmetrically reaming the endplates, thus reducing bone loss during reaming and preserving the vertebral body strength. In our case series, we modified the laparoscopic technique in order to insert a single, large, trapezoidal cage (SOVEREIGN, Medtronic) that was originally designed for insertion using an open transperitoneal or retroperitoneal approach. This particular cage due to its shape and size, allows for better restoration of the lumbar lordosis with 12 degrees, while also providing adequate surface for intervertebral stabilization and a large quantity of graft placement, thus securing the fixation.

Arthrodesis materials have also progressed from autogenous bone graft to the use of either allografts or rhBMP-2 which eliminate donor site morbidity and reduce operative time, while at the same time give similar or even superior fusion rates with the use of autografts (2,23,24). Nevertheless, recent studies suggested an increased number of adverse events associated with the use of rhBMP, (14) so in our case series we chose to use a human allograft, specifically cancellous bone chips and demineralized bone matrix (DBM, Grafton) with excellent results.

MATERIALS AND METHODS

Over a period of two years, twelve consecutive patients underwent single level laparoscopic anterior lumbar interbody fusions at the L5-S1 level, and in one trauma case, at the L4-L5 level. Operative indications included chronic low back pain secondary to degenerative disc disease, spondylolisthesis, failure of previous posterior interbody fusion and trauma (Figure 1A-C).

Patients with degenerative disc disease had failed at least 6 months of non-operative treatment before they became eligible for the operation. The rest of the cases were candidates for the operation as soon as the diagnosis of their pathology was made. In all patients, preoperatively Spiral Computer Tomography (CT) scanning was done in order to identify details of metalwork failure and the extent of the osteophytes around the foramen that might cause pressure to the nerve roots during the reduction manoeuvre. This was the single most important factor in determining whether a 360 or a 540-degree fusion would be performed. In any case in which reduction was judged likely to cause neurological disorders, a 540-degree fusion was undertaken,



Figure 1A-C: Patient presentation imaging examples demonstrating failure of previous posterior fusion, spondylolisthesis and trauma.

that provided initial posterior decompression for nerve root protection. The surgery, apart from the LALIF procedure, included posterior instrumentation and graft placement in order to secure the spinal fusion in all patients.

A 540-degree fusion was performed in the spondylolisthesis, the revision and one of the degenerative cases, while the rest of the patients underwent a 360-degree fusion.

The surgical technique for the modified LALIF procedure used in this series was performed in the following way: The 540-degree fusion operations started by placing the patient prone on a Jackson spinal table, with a Kambin frame that allowed the abdomen of the patient to hang freely. The patient was then connected to a neuromonitoring device that allowed for continuous monitoring of spinal nerve integrity during the surgery. Following a standard surgical exposure with posterior midline incision and exposure of the tips of the transverse processes bilaterally, extended laminectomy with removal of the facets was performed in the spondylolisthesis and the degenerative disease cases. In the three revision cases, instrumentation removal was performed, followed by thorough debridement of the transpedicular screw holes and in one particular case, insertion of a TLIF type cage at another disc level (L3-L4) as this was judged necessary by the spinal surgeon. Pedicle screws were then placed under fluoroscopic control, completing the first part of the procedure. In the revision cases, care was taken to place the new transpedicular screws in new holes with different direction or purchase of mostly healthy bone.

The patient was then placed in a supine position and the laparoscopic part of the procedure was initiated. In the cases where a 360-degree fusion had been judged safe to perform, the operation started straight with this part. Pillows were placed under the hips of the patient to augment lumbar lordosis at the lumbosacral junction and to establish a straight line between the sacral promontory and the upper end of the pubic symphysis that was verified using fluoroscopic control. Pillows were also placed beneath the patient's knees to prevent hyperextension. After applying ankle straps for safety, the patient was placed in a Trendelenburg position in order to achieve cephalad retraction of the abdominal viscera. A standard laparoscopic approach was then performed by an experienced general surgeon in co-operation with the spinal surgeon. The three standard laparoscopic ports were utilized. The first incision was the curvilinear umbilical incision through which the pneumoperitoneum was maintained and the camera was placed. A low left paramedian incision was used for the working forceps portal. The main working incision was centered over the midline supra-pubic region and measured 1.5 cm in length.

After placing the trocars in the ports and establishing the pneumoperitoneum, the sigmoid colon was retracted to the left using laparoscopic retractors and tacked to the abdominal wall in order to gain exposure of the sacral promontory. The sacral promontory was identified using fluoroscopy and the posterior peritoneum was opened sharply. In order to

avoid damaging the presacral sympathetic plexus, a blunt Kittner dissector and small gauze balls were utilized for gentle mobilization of the plexus with slow, gentle sweeping manoeuvres. This manoeuvre in combination with the minimal use of electrocautery in this region and the excellent camera visualization that the approach offers helped reduce the incidence of retrograde ejaculation in this series to zero. The midline sacral artery and vein were then cut and ligated using a special 5mm ultrasonic device (Harmonic scalpel, Ethicon inc) that significantly reduces thermal damage to the surrounding tissues, as well as smoke in the operative field.⁸ After the L5-S1 disc was exposed, the iliac vessels were mobilized and held out of the operative field by means of 4 thick Kirschner Wires (K-Wires) that were placed at each corner of the intervertebral disc space using a power drill (Figure 2A,B) The use of the power drill for the insertion of the K-Wires was necessary in order to prevent accidental extraction that might cause rupture of the iliac, especially the left, vein.

In the single case (trauma) where the traumatized disc space was the O4-O5, the aorta and the vena cava were prepared and mobilized together to the right side. The four K-Wires were also placed in that case to clear the operative field from the posterior peritoneum. After confirmation of the midline, the instrumentation phase was initiated. The lateral width of the discectomy was determined using a discectomy template, the annulus over the disc space was divided and a trephine and endo-rongeurs were used to perform block discectomy. The end-plates were then

prepared using a disc shaver and the appropriate footprint template was inserted to ensure that the posterior disc space preparation was adequate. Progressively larger 12-degree distractor trials were then driven into the disc space to restore the native disc space height and the natural lordosis of the vertebral segment to the appropriate level (Figure 3A,B).

During the disc-space preparation, fluoroscopic control was very important in order to ensure that the different instruments reached the posterior end of the lower end-plate so that the cage would reach the correct position.

The appropriate cage (SOVEREIGN, Medtronic) was then prepared and inserted into the abdomen and subsequently into the disc-space using a specially modified technique. Cage preparation included filling the cage with allograft, in particular cancellous bone chips mixed with demineralized bone matrix (DBM, Grafton), and then covering the implant with a gel-covered latex glove. A tricky part of the procedure was the insertion of the large trapezoid cage 23mm wide through the relatively small incision of the 15mm trocar, and the gel-covered latex glove did the trick of facilitating the insertion through the soft and flexible anterior abdominal wall (Figure 4A-C).

The straight line between the sacral promontory and the supra-pubic incision was crucial for the correct implantation of the cage. The insertion of the large 12-degree lordotic cage resulted by itself in reduction of the spondylolisthesis in the spondylolisthesis cases and in restoration of the native disc space and the lumbar lordosis in the rest of the patients.

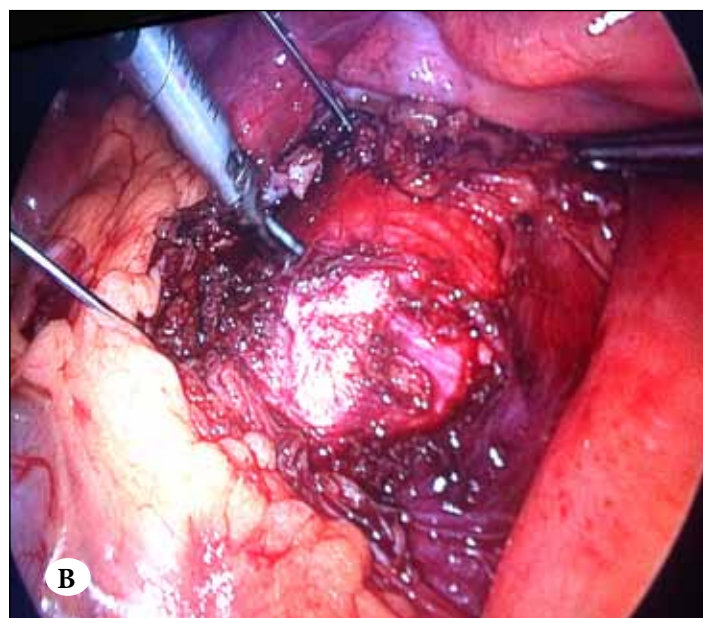


Figure 2A,B: The K-Wires in place, clearing the operative field of the iliac veins and the posterior peritoneum.

After fluoroscopic confirmation of correct implant placement and alignment, the K-Wires were very carefully retracted, in order to avoid damage to the iliac vessels, the posterior peritoneum was reapproximated and the incisions were closed. The patient was then placed once again in the prone position for the last part of the operation, which was placement of the transpedicular screws and rods with partial facet excision and graft placement. This part of the procedure was completed in a minimally invasive fashion in one of the degenerative cases and in the trauma case, 360-degree cases, using a percutaneous approach and special equipment (CD Horizon Sextant II, Medtronic), and in an open fashion in the spondylolisthesis cases, one of the degenerative and the revision cases. In these patients the transpedicular screws were already in place, and only the rods and graft had to be placed (Figure 5A-C).

Postoperative care included a liquid diet and patient-controlled analgesia. Patients were discharged when the

pain was controlled by oral analgesics alone, at a mean time of 4 days post-op, with the exception of one revision patient who was diagnosed with septic loosening and Acinetobacter infection in one of the extracted screws and required two weeks of hospitalization for administration of intravenous antibiotics. Patients were allowed free and unrestricted mobilization as soon as they were able to. Follow up visits were scheduled at 1 week, 1,5 months, 3 months, 6 months and 1 year postoperatively. Visual Analog Scale and Oswestry Disability Index scores were recorded preoperatively and at 1 year postoperatively. Fusion was assessed at twelve months post-op by evaluating callus formation in Spiral CT scans.

RESULTS

From October 2010 until May 2013, twelve patients underwent either a 360- or 540-degree laparoscopic anterior lumbar interbody fusion with a single, large, ALIF type cage. Indications for the surgery included spondylolisthesis (3), revision of failed posterior lumbar fusion with loose

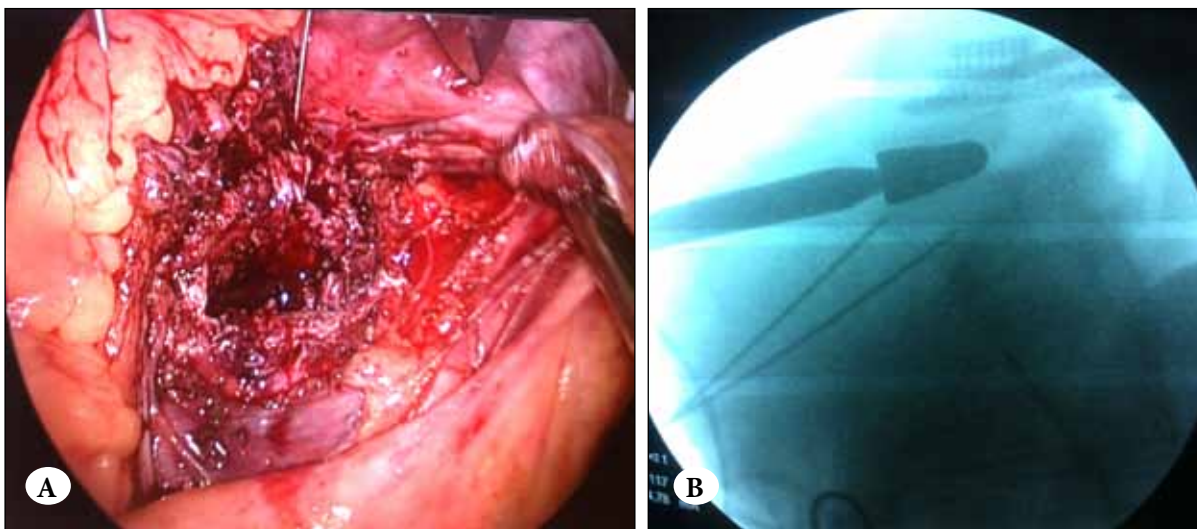


Figure 3A,B: Disc material removal and usage of a 12-degree distractor trial to restore disc space height.



Figure 4A-C: Cage preparation and implantation through the anterior abdominal wall to the prepared disc space.

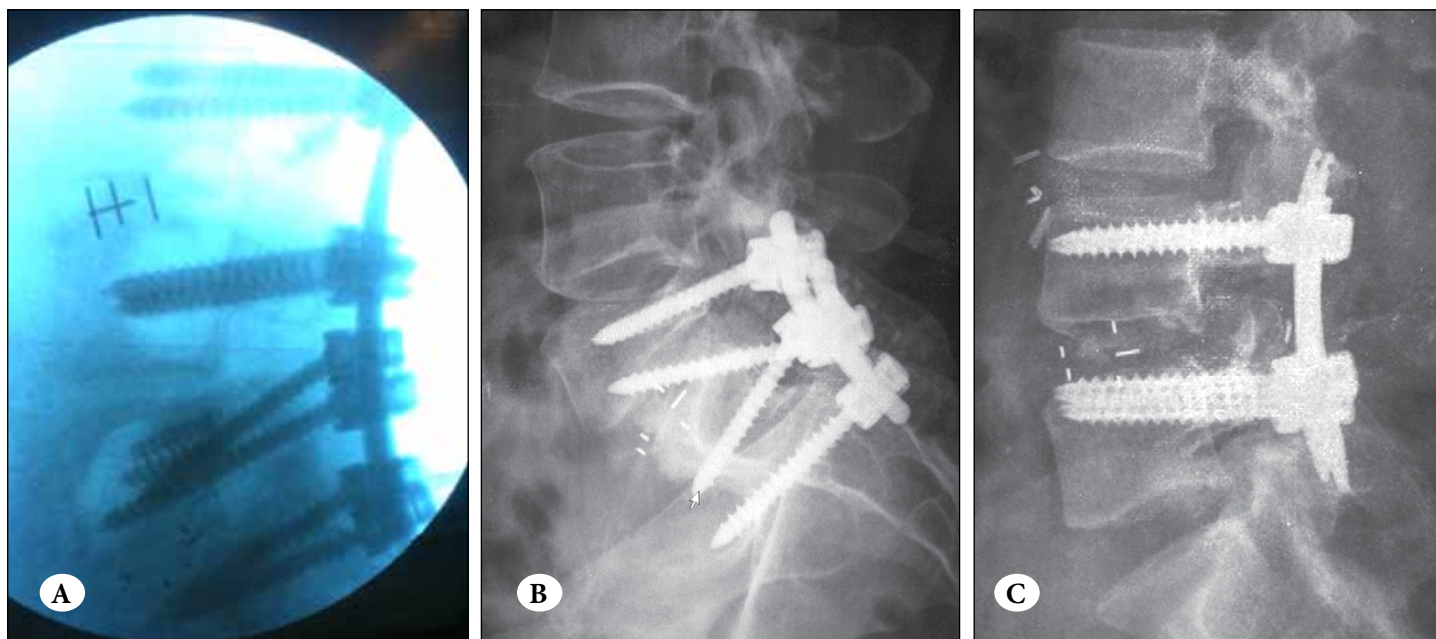


Figure 5: ALIF cage and posterior instrumentation in place, in one of the revision cases, one spondylolisthesis and the trauma case.

Table 1: Prevailing symptom in relation to the underlying pathology

	Failed fusion	Spondylolisthesis	Degenerative disease	Gun-shot trauma
Low back pain	2	2	2	
Sciatica		1		1
Neurological deficit	1	1		
Sciatica and Neurol. deficit	1			
Trauma				1

screws in various levels (5), degenerative disc disease (3) and trauma (1). Mean patient age was 48 years (range 27-72). Seven patients were female and five were male. The prevailing symptom in almost all patients was low back pain while sciatica and neurological deficit were also present in some of the cases Table 1.

No case required a conversion to an open procedure. Mean operative time was 270 min (range 185 to 360). Significantly longer operative time was required for the 540-degree fusions (320 min average, range 280 to 360) than for the 360-degree (210 min average, range 185 to 240). In all the patients of this series both the ALIF cage and the posterior instrumentation were placed successfully and confirmed fluoroscopically intraoperatively. Mean hospital stay was 5 days (range 1-14 days). No intraoperative complications occurred in any patient and estimated blood loss was less than 200 ml in all cases.

Post operative complications included two cases of paralytic ileus (2 patients, 16,6%) that were treated conservatively and these patients had a prolonged hospital stay of 5 and 6 days respectively. In one of the revision cases, cultures obtained intraoperatively from one of the loose screws, came up positive with *Acinetobacter*, indicating it was a septic loosening. Thorough intraoperative debridement had already taken place in all revision screw holes and new transpedicular screws were always placed in new holes, so the patient was simply treated by administration of intravenous antibiotics for 2 weeks followed by per os antibiotics for three months. That particular patient has a two year follow up, being by now pain-free with no signs of infection on the last Magnetic Resonance Imaging (MRI) of her lumbar spine. No cases of retrograde ejaculation occurred in our series. Follow-up time ranged from 42 months for the first case to 18 months for the last in this series (mean 28 months).

Solid fusion was achieved in all patients as demonstrated by the spiral CT scan, done one year after surgery. The duration and severity of post-op pain varied greatly with some cases being pain-free one month after surgery, particularly the younger patients, while others necessitated over six to eight months for the pain to subside, especially the spondylolisthesis. At one year postoperatively, all patients were virtually pain-free. This was reflected at the significant Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores improvement. More specifically, the VAS dropped from an average 7.8 pre-op to 1.6 one year post-op and the ODI from 39 to 14 respectively ($p < 0.01$ for both indexes, Wilcoxon signed rank test). Overall patient satisfaction with the operation was accessed using the Patient Satisfaction Index (PSI) (5) as shown in Figure 6. A satisfactory outcome, defined as 4 or 5 on the PSI was achieved in 91.6% (11/12) of the patients.

DISCUSSION

Since the first description of the LALIF technique, there have been numerous publications evaluating its safety and efficacy in both the L4-L5 and the L5-S1 levels (1,10, 17, 34,37). There have also been studies comparing the operation with other techniques like the traditional open ALIF and the open mini-ALIF retroperitoneal procedures (5,21,33). Laparoscopic ALIF for L4-L5 level fusions has greatly been abandoned due to two main reasons. First, the complication rate and particularly the retrograde ejaculation rate has been shown to be unacceptably high (22, 33). Secondly, other techniques exist that give acceptable results. In particular, either the DLIF or the TLIF procedure and cages give acceptable results for this level of the spine (18, 27). On the contrary, for the L5-S1 level, the laparoscopic technique as performed in this series appears to have several advantages and at the same time minimal morbidity, thus making it a promising technique for difficult fusion cases in this region.

It is by now well known that the main reason for spinal fusion failure is inability to restore lumbar lordosis (20). This may also lead to acceleration of adjacent level degeneration and necessitate re-operation.⁷ Lumbar lordosis is normally 40-50 degrees, with two lower discs contributing about 50% to this value. Effective lumbar lordosis restoration, meaning 12-18 degrees in the L5-S1 level, is only possible with the large lordotic ALIF type cages, traditionally inserted using an open technique. In contrast, laparoscopic placement of cylindrical cages usually fail to restore lumbar lordosis and may lead to fusion failure (7, 13). In our modification of the



Figure 6: PSI, evaluated from the patient's answer to the simple question: "Would you undergo the same operation for the same result?" The possible answers were: 1 = definitely no, 2 = probably no, 3 = I don't know, 4 = probably yes, 5 = definitely yes.

ALIF technique, we were able to insert a large lordotic ALIF type cage through a relatively small incision, that effectively restored 12 degrees of lumbar lordosis, thus restoring normal sagittal balance of the lumbar spine. In osteoporotic bone, the large cage surface also prevented shrinking of the endplates, while it is a contraindication for the TLIF cages. In addition the large cage provided enough surface for graft placement and adequate support to the lumbar spine, that together with the posterior instrumentation resulted in the 100% fusion rates observed in this series.

At the same time, it has been well documented that the complication rate at this level with the laparoscopic technique is comparable with the open techniques while having all the advantages of a minimal invasive surgery (less surgical trauma, less blood loss, less hospitalization time and faster mobilization) (10, 17). Moreover we demonstrated that we were able to reduce the incidence of retrograde ejaculation to zero with careful manipulation of the presacral plexus due to excellent visualization.

We therefore propose that the modified LALIF technique is a viable alternative to the open technique of anterior lumbar fusion and represents a possible solution for demanding L5-S1 fusion cases. We anticipate larger studies to verify and validate our results.

CONCLUSION

The laparoscopic anterior lumbar interbody fusion when done with a single, large, lordotic cage and combined with posterior fixation, appears to be a safe and effective technique for demanding L5-S1 fusion cases.

REFERENCES

1. Begloubter N, Zamir O, Milgrum M, et al. Laparoscopic anterior lumbar interbody spinal fusion. *Harefuah* 142(5):326-328, 400, 2003
2. Burkus JK, Heim SE, Gornet MF, Zdeblick TA. Is INFUSE bone graft superior to autograft bone? An integrated analysis of clinical trials using the LT-CAGE lumbar tapered fusion device. *J Spinal Disord Tech* 16:113-122, 2003
3. Capener N. Spondylolisthesis. *Br J Surg* 19:374-386, 1932
4. Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: Emerging safety concerns and lessons learned. *Spine J* 11(6):471-491, 2011
5. Chung SK, Lee SH, Lim SR, et al. Comparative study of laparoscopic L5-S1 fusion versus open mini-ALIF, with a minimum 2-year follow-up. *Eur Spine J* 12(6):613-617, 2003
6. Cloward RB. The treatment of ruptured lumbar intervertebral discs by vertebral body fusion. *J Neurosurg* 10:154-168, 1953
7. Dimar JR, Glassman SD, Vemuri VM, Esterberg JL, Howard JM, Carreon LY. Lumbar lordosis restoration following single-level instrumented fusion comparing 4 commonly used techniques. *Orthopedics* 34(11):e760-764, 2011
8. Fitzgerald JE, Malik M, Ahmed I. A single-blind controlled study of electrocautery and ultrasonic scalpel smoke plumes in laparoscopic surgery. *Surg Endosc* 26(2):337-342, 2012
9. Flynn JC, Hoque MA. Anterior fusion of the lumbar spine. End-result study with long-term follow up. *J Bone Joint Surg Am* 61(8):1143-1150, 1979
10. Frantzides CT, Zeni TM, et al. L5-S1 Laparoscopic Anterior Interbody Fusion. *JLS* 10(4):488-492, 2006
11. Freebody D, Bendall R, Taylor RD. Anterior transperitoneal lumbar fusion. *J Bone Joint Surg* 53(4):617-627, 1971
12. Garg J, Woo K, Hirsch J, Bruffey JD, Dille RB. Vascular complications of exposure for anterior lumbar interbody fusion. *J Vasc Surg* 51(4):946-950, 2010
13. Goldstein JA, Macenski MJ, Griffith SL, McAfee PC. Lumbar sagittal alignment after fusion with a threaded interbody cage. *Spine* 26(10):1137-1142, 2001
14. Greenough CG, Peterson MD, Hadlow S, Fraser RD. Instrumented posterolateral lumbar fusion. Results and comparison with anterior interbody fusion. *Spine* 23(4):479-486, 1998
15. Harmon PH. Anterior excision and vertebral body fusion operation for intervertebral disc syndromes of the lower lumbar spine. *Clin Orthop Relat Res* 26:107-127, 1963
16. Holte DC, O'Brien JP, Renton P. Anterior lumbar fusion using a hybrid interbody graft. A preliminary radiographic report. *Eur Spine J* 3:32-38, 1994
17. Inamasu J, Guiot BH. Laparoscopic anterior lumbar interbody fusion: A review of outcome studies. *Minim Invasive Neurosurg* 48(6):340-347, 2005
18. Islam MA, Sakeb N, Sarker SK. Single space transforaminal lumbar interbody fusion in spondylolisthesis: initial experience of 30 cases. *Bangladesh Med Res Counc Bull* 39(2):47-51, 2013
19. Iwahara T. A new method of vertebral body fusion. *Surgery* 8: 271-287, 1944
20. Jang JS, Lee SH. Postoperative Sagittal Imbalance after Lumbar Fusion Surgery. *J of Advanced Spine Surgery* 2(1):20-31, 2013
21. Kaiser MG, Haid RW, Subach BR, Miller JS, Smith CD, Rodts GE. Comparison of the mini-open versus laparoscopic approach for anterior lumbar interbody fusion: A retrospective review. *Neurosurgery* 51(1):97-103, 2002
22. Katkouda N, Campos GM, Mavor E, Mason RJ, Hume M, Ting A. Is laparoscopic approach to lumbar spine fusion worth- while? *Am J Surg* 178(6):458-461, 1999
23. Kleeman TJ, Ahn UM, Talbot-Kleeman A. Laparoscopic anterior lumbar interbody fusion with rhBMP-2. A prospective study of clinical and radiologic outcomes. *Spine* 26(24): 2751-2856, 2001
24. Kozak JA, Heilman AE, O'Brien JP. Anterior lumbar fusion options. Technique and graft materials. *Clin Orthop Relat Res* 300:45-51, 1994
25. Kozak JA, O'Brien JP. Simultaneous combined anterior posterior fusion: An independent analysis of a treatment for the disabled low back pain patient. *Spine* 15:322-328, 1990
26. Kuslich SD, Ulstrom CI, Griffith SL, et al. The Bagby and Kuslich method of lumbar interbody fusion. History, technique, and 2- year follow-up results of a United States prospective, multicenter trial. *Spine* 23:1267-1278, 1998
27. Potter BK, Freedman BA, Verwiebe EG, Hall JM, Polly DW, Kuklo TR. Transforaminal lumbar interbody fusion: clinical and radiographic results and complications in 100 consecutive patients. *J Spinal Disord Tech* 18(4):337-346, 2005
28. Reagan JJ, Aronoff RJ, Ohnmeiss DD, Sengupta DK. Laparoscopic approach to L4-L5 for interbody fusion using BAK cages: Experience in the first 58 cases. *Spine* 24(20):2171-2174, 1999
29. Reagan JJ, Yuan H, McAfee PC. Laparoscopic fusion of the lumbar spine: Minimally invasive spine surgery. A prospective multicenter study evaluating open and laparoscopic lumbar fusion. *Spine* 24(4): 402-411, 1999
30. Sasso RC, Kenneth burkus J, Lehuac JC. Retrograde ejaculation after anterior lumbar interbody fusion: Transperitoneal versus retroperitoneal exposure. *Spine* 28(10):1023-1026, 2003
31. Stauffer RN, Coventry M. Anterior interbody lumbar spine fusion: Analysis of Mayo Clinic studies. *J Bone Joint Surg Am* 54:756- 768, 1972
32. Tiisanen H, Seitsalo S, Osterman K, Soini J. Retrograde ejaculation after anterior interbody lumbar fusion. *Eur Spine J* 4(6):339-342, 1995
33. Zdeblick TA, David SM. A prospective comparison of surgical approach for anterior L4-L5 fusion: Laparoscopic versus mini anterior lumbar interbody fusion. *Spine* 25(20):2682-2687, 2000
34. Zdeblick TA. Laparoscopic spinal fusion. *Orthopedic Clinics of North America* 29(4):635-645, 1998
35. Zdeblick TA, Phillips FM. Interbody cage devices. *Spine* 28(15 suppl):S2-S7, 2003
36. Zdeblick TA, Ulschmid S, Dick JC: The surgical treatment of L5-S1degenerative disc disease. A prospective randomized study. 10th Annual Meeting, North American Spine Society, Washington, DC, 1995:168
37. Zucherman JF, Zdeblick TA, Bailey SA, Mahvi D, Hsu KY, Kohrs D. Instrumented laparoscopic spinal fusion: preliminary results. *Spine* 20(18):2029-2035, 1995

Manuscript submitted April 18, 2014.

Accepted June 12, 2014.

Address correspondence to: Dimitrios Moschos, Orthopaedic Department, Hippocraton General Hospital, Thessaloniki, Greece

Phone: +693 966 28 69

email: dmoschos8@gmail.com