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Laparoscopic lumbar spine surgery

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Abstract The use of transperitoneal endoscopic approaches to the distal segments of the lumbar spine has recently been described. This has been the catalyst for the development of other minimally invasive anterior approaches to the spine. This review looks at the published results so far, and highlights the principles, techniques and complications. The limitations of laparoscopic approaches have meant that surgeons are moving on to endoscopic extraperitoneal and mini-open ap-

proaches, but important lessons have been learnt during this short rapid phase of development. The efficacy and safety of minimal access techniques in the spine have been established, and outcome standards set by which future techniques can be judged. The importance of proper training is emphasised.

Key words Laparoscopy · Anterior fusion · Lumbar spine · Minimally invasive spine surgery · Review

Introduction

There have been very rapid advances in the last decade in the surgical management of lumbar spinal disease. Whilst clinical assessment and decision making continue to play the most important role in determining the outcome of interventions, modern technology has played a key role in this revolution. It seems inevitable that the advances in the next decade will be biological rather than mechanical, and the changes in the last few years may be the last major contribution that clinic-based operating surgeons will be able to make in this field.

Advances in surgical technique can be considered either in relation to approaches to the spine or in relation to the nature of the surgical procedure performed on the spinal column.

The posterior approaches to the spine have evolved by the use of the posterolateral percutaneous portal.

The anterior approach to the spine, which previously had been open, either transperitoneal or retroperitoneal, has changed rapidly because of the development of endoscopic and retractor technology. The catalyst for this development

has undoubtedly been the application of transperitoneal endoscopic techniques to approaching the lumbosacral disc. The approach, which was first described for discectomy in 1991 [11], was further developed to perform anterior lumbar intervertebral fusion (ALIF) [6, 8, 15, 20]. This was partly brought about by the use of cylindrical fusion cages and the ability to introduce them through cannulae.

In most surgeons' hands, the transperitoneal endoscopic or laparoscopic technique proved practicable only at the lumbosacral disc level, and because of the steep learning curve and significant complications many groups have moved on to retroperitoneal endoscopic techniques, or mini-open techniques, with specialised retractor systems [7], which are covered elsewhere in this paper.

Nonetheless, it has been the development of the laparoscopic techniques that has opened up the whole field, and there are many useful lessons to be learnt from its history, albeit short lived.

Throughout the development of these techniques, the importance of general surgical support for these approaches, and for careful supervised training, including animal, cadaveric and simulation models, has been emphasised.

History

Laparoscopic discectomy was first described in 1991 [10]. This case report of a young male patient with an L5/S1 herniation, performed by the transperitoneal route with simultaneous endoscopic video and fluoroscopic guidance, demonstrated the relative ease of access to this disc, and in this instance was performed on an out-patient day-case basis. The same group [2] further described the technique, and reported on 15 cases of laparoscopic discectomy in 1995. It is of note that by their report of 1996 [11], they had moved on to a retroperitoneal approach, which they felt was easier and safer, especially at L4/5 and above.

In 1995, a variant of the discectomy technique was described [19], where the disc was approached and visualised endoscopically via the transperitoneal approach, and then discectomy was performed with the percutaneous nucleotome, which had been introduced under direct vision.

Many of the surgical groups developing this technique used animal and cadaveric models, although the first report of the use of an animal model [18] came after the early clinical results were reported. Techniques and results were reported in six pigs, in three of which a transperitoneal approach was used. They found the transperitoneal route technically easier, with good access to the spine and minimal complications.

Laparoscopic fusion in humans was first reported in 1994, but published in 1995. The first published series [8] was a report of complications in 100 endoscopic spinal surgeries, of which 22 were laparoscopic fusion cases. The report, which concerned a multicentre study that formed part of an American Food and Drug Administration (FDA) investigational device exemption (IDE) study for the BAK cage, appeared to establish the safety of the approach, in a small case series.

The next report [6] concerned a series of six patients, five of whom had a successful L5/S1 laparoscopic fusion with bone dowels, and in one of whom the endoscopic approach was abandoned because of iliac vein laceration.

Two further studies [15, 20] reported 17 and 34 cases, respectively, of laparoscopic spinal fusion, and both described the approach to the L4/5 as well as the L5/S1 disc.

European groups performing this technique have reported more recently [3, 12].

Indications

There is general agreement about the indications and contraindications for the laparoscopic approach to the lumbar spine. Patients who have been selected for anterior lumbar interbody fusion will often have low back pain that has been refractory to non-operative treatment. Imaging will have revealed low-grade isthmic spondylolisthesis, spondylolysis in an older age group, degenerative spondylolisthesis, pseudarthrosis following previous attempted poste-

rior arthrodesis, or degenerative disc disease with strongly positive pain provocation studies. All such patients with mono- or bi-segmental disease can be considered for laparoscopic ALIF. In most surgeons' hands, the approach is restricted to the lumbosacral disc alone, but if the general surgical expertise is available, then the L4/5 disc can be considered as well.

The contraindications are few. Many surgeons will not consider any transperitoneal approach, including laparoscopic, in young male patients who have not yet fathered a family. It is not possible to ascertain the rate of presacral nerve injury leading to retrograde ejaculation and infertility from the small number of reported cases in the literature. There is a philosophical argument that it is easier to visualise and avoid the presacral nerves with the clear view and magnification obtained with the laparoscope. However, this potential complication is obviated by the use of retroperitoneal approaches using blunt dissection, and for this reason this group should only be considered if participating in a fully informed prospective trial where the presence of retrograde ejaculation is actively sought in follow-up assessments.

Previous anterior spinal surgery and significant previous peritoneal disease or surgery are contraindications to laparoscopic spinal surgery; previous laparoscopic pelvic or abdominal surgery is not, but patients should be advised of the higher chance of open conversion.

Operative technique

The laparoscopic approach to the distal lumbar spine is best performed by a team that includes a general surgeon specifically trained in laparoscopic techniques. Under general anaesthetic, the patient is positioned supine on the operating table. A radiolucent table aids intraoperative imaging, and abduction and flexion of the hips both allows the surgeon to work from between the legs and relaxes the tension on the aorto-iliac and ilio-caval vessels. A 30° Trendelenburg position assists later retraction of the intestines. Bladder catheterisation is mandatory to avoid bladder injury from cannula insertion.

There are a variety of portal strategies possible, but the working portal for instrumenting the L5/S1 disc should be in the midline of the abdominal wall, and at the point where a line, determined on fluoroscopy, which is the axis of the disc on a lateral view, meets the surface. In addition a midline port in the region of the umbilicus is required for the endoscope. Two or, more commonly, three subsidiary working ports, for suction/irrigation, retractors, etc, can be introduced laterally under direct vision. There are two choices for insertion of the first port. The blind technique using insufflation with a Veres needle carries the risk of visceral penetration and insufflation, and most sources now recommend an open technique where the peritoneum is opened under direct vision and the portal inserted without a sharp

trocars. Portals must have a cuff to prevent leakage of gas. Carbon dioxide insufflation now follows, using a pressure- and volume-regulated supply. Ten-millimetre 0° and 30° endoscopes are used, and a scope warmer helps prevent misting. Most instruments that are used in the peritoneal cavity are electrically insulated except at the tip to prevent diathermy injury to abdominal contents outside the field of view of the endoscope.

The parietal peritoneum is identified over the sacral promontory, and retractors are used to prevent intraperitoneal contents impinging on the field of view. The parietal peritoneum overlying the L5/S1 disc is divided under direct vision, to expose the extraperitoneal connective tissue and median sacral artery. By incising the parietal peritoneum to the right and by visualising the main branches of the presacral plexus, inadvertent injury should be avoided. The median sacral artery is ligated or clipped, and, with endoscopic vascular retractors to protect the iliac vessels, the exposure of the L5/S1 disc is complete.

The approach to the L4/5 disc, which is described in detail in a recent report [16], is more technically demanding. After opening the peritoneum at the base of the sigmoid mesocolon, the left iliac artery and vein are mobilised, often after ligation and section of the segmental vessels and iliolumbar vein. The vessels are then all retracted over to the right with endovascular retractors, thus exposing the disc. Approaches to higher levels have been described.

Results

The reported results of laparoscopic surgery can be broken down into two areas. The results of the approach, which is the focus of this review, and the results of the spinal procedure such as discectomy or fusion. Approach-specific results, such as length of scar, mobilisation times, and complications, can be altered by the spinal procedure performed, but are important to review as they have established the clear advantages of the minimally invasive approach concept. The outcomes of the specific spinal intervention will be discussed elsewhere in this issue.

The published results are in three groups. The initial reports were of single case reports or small series, which established the basic principles, efficacy and safety of the approach [2, 10, 11, 29]. The second group were more extensive case series, often prospective, and reported by some of the pioneers in the field [5, 15]. More recently, some comparative studies have appeared [12, 16], although no randomised prospective study of significant size, and comparing different anterior approaches, has been published or, to the knowledge of this author, are currently being performed.

In an early reported series of six patients [6] who underwent attempted laparoscopic L5/S1 fusion with bone dowels, one patient required open conversion because of venous bleeding. In one patient the laparoscopic approach was possible despite previous major abdominal surgery,

Table 1 Mobilisation times (days) (ALIF anterior lumbar interbody fusion)

Approach	Laparoscopic	ALIF 1-level	ALIF 2-level
Time to sitting	0.8	2.2	2.8
Time to walk	1.9	3.5	5
Post op discharge	4.6	6	7

after extensive dissection of intra-abdominal adhesions. The operative time ranged from 200 min to 300 min (mean 245 min), with an average estimated blood loss of 350 cc (range 0–1000 cc). The average hospital stay was 4.2 days (range 3–5 days).

In a consecutive series of 17 patients reported in 1995 [20], laparoscopic fusion with BAK cages was performed in three centres. The approach-related outcomes were reported as follows. Two patients early in the series required open conversion to control bleeding. Blood loss was negligible in the other cases, and prolonged ileus occurred in three patients. The operative time ranged from 80 min to 6 h for the single-level cases, 4.5 to 7 h for the two-level cases. The hospital stay ranged from 0 to 6 days, with an average of 2 days.

In our own series [12], a prospective non-randomised study of 48 anterior BAK cage cases was performed, representing the early learning curve for the three surgeons involved. Twenty-three cases were primary open extraperitoneal cases, of which 13 were two-level cases. Of 25 attempted laparoscopic cases, 3 required open conversion.

The one-level open cases were compared with the one-level laparoscopic cases. The operating time and mean blood loss were better for the laparoscopic (135 min and 107 ml respectively) than the open cases [193 min ($P = 0.06$) and 888 ml ($P = 0.03$) respectively]. Mobilisation parameters, which correlate with outcomes related to the approach, were all significantly ($P < 0.05$) shorter for the laparoscopic approach (Table 1).

The largest series to date [16] reports 240 consecutive laparoscopic BAK cage cases performed by 19 surgeons in ten North American medical centres, between 1994 and 1996. They were compared with a cohort of 591 patients who underwent open ALIF using the same cage device over a period from 1992 to 1995, performed by 42 surgeons at 19 centres. They found that the operative time was longer in the laparoscopic group (average 201 min) than in the open group (average 142 min). A significant learning curve associated with the laparoscopic procedures was demonstrated in the results of eight surgeons, with the operative time decreasing from a mean of 215 min for the first five cases in each of their series, to a mean time of 165 min in the last five cases in the series. Operative blood loss and hospital stay were both significantly shorter in the laparoscopic group, although even in experienced hands, the stay for one-level laparoscopic fusion was 3.3 days.

Complications

The complications of the approach are nearly all in the intraoperative, or early postoperative period. The first significant report on laparoscopic fusion [8] was a report of complications in 22 laparoscopies, and the only significant complication of the approach was a left common iliac vein tear, which required open conversion.

Open conversion should never be considered as failure, but rather represents wise surgical decision making. It may be performed for arterial or venous bleeding [6, 8, 12, 16, 20], because of difficulty with endoscopic access to the spine [4, 12, 16], or because of technical problems with implant insertion that could not be corrected endoscopically [16]. Vascular injuries were reported in most series, but all were treated successfully, most by open conversion, and there was no identifiable impact on other outcome parameters. In our series [12] there were three large vessel injuries (12%), but in the recent large series [16], there were no such injuries in the one-level endoscopic group, compared to two (0.7%) in the open group.

It is difficult to measure the likely rate of presacral nerve injury, but in the largest reported series to date [16], the numerical incidence of retrograde ejaculation was found to be higher in the laparoscopic group than the open group, although the difference did not reach statistical significance. They report that 5 of the 11 cases with retrograde ejaculation following laparoscopic surgery resolved spontaneously.

Post-operative ileus appears to occur equally frequently with laparoscopic and open approaches to the spine [16], and in the same comparative series, wound dehiscence, which occurred in 1% of open cases, was not reported in the endoscopic cases.

In our series [12], there was a significant rate (36% laparoscopic and 13% open) of new, or recurrence of previous, nerve root pain. Two of these were due to implant malposition. We believe that most of these nerve root pains were implant rather than approach related, but it is possible that malpositioning of cage devices is more frequent in endoscopic cases, although this has not been demonstrated scientifically to date.

Discussion

Laparoscopic approaches to the lumbar spine have been clearly established as a minimally invasive way of accessing the anterior aspect of the distal lumbar spine. For one-level disease (L5/S1), it is probably the quickest and easiest approach to the spine. The limitations relate to the difficulty of access to more proximal disc levels [3, 12], and only a small number of surgeons [16, 20] can routinely and safely approach L4/5 and above laparoscopically. Partly because of this, and partly because the approach skills are very alien to surgeons brought up with open anterior retroperitoneal approaches, most groups are now develop-

ing either the endoscopic extraperitoneal approaches, or most popular of all, producing sophisticated retractor systems that allow open access through a small incision. In pre-reproductive males, many surgeons will not use a transperitoneal route because of the risk of infertility.

General and orthopaedic surgeons performing this surgery should be fully trained, first by the use of cadaveric and animal simulation, and then by a formal process of proctoring and supervision. The usefulness of porcine models has been described [9, 13, 18], and this appears to be an optimal simulation of human laparoscopy from an anatomical and surgical point of view. A learning curve has been demonstrated [16], and this must be factored in when beginning this type of surgery, and in consenting patients for these procedures. It seems that in the future the introduction of new technologies will be more rigidly policed, and the development of laparoscopy has demonstrated the importance of reporting early results, using simple operative outcomes to establish safety and efficacy. Some of the problems encountered reinforce the need for all such development to occur in centres committed to scientific reporting of their results, whether good or bad.

The cost implications of laparoscopic techniques specifically, and minimally invasive approaches in general, have not been reviewed here. The cultural variation in methods of costing surgical interventions does not allow extrapolation from country to country. There is a significant cost associated with the non re-useable ports and endoscopic instruments, although many of these are available in a re-useable form. It has been shown, however, that patient mobilisation and discharge times are significantly shorter with laparoscopic spinal fusion, and in some healthcare systems this will equate with lower cost. It certainly is of benefit to individual patients.

The ability to perform the required surgical procedure on the spine through a minimal access approach has been questioned in some animal and biomechanical studies. In one [17], it was shown histologically that a less effective discectomy was performed endoscopically, and end plate decortication was also superior in the open group. This aspect requires further study, especially in relation to the newer emerging approach techniques.

The advent of laparoscopic surgery has allowed the development of surgical procedures using a hybrid of the new and emerging technologies available, including the insertion of biologically active cages [1], and the use of surgical guidance systems. Minimally invasive surgical techniques will probably remain an important part of the high-technology solutions now evolving for the treatment of spine disease.

Conclusion

The use of transperitoneal laparoscopic approaches to the spine has played a major role in initiating the develop-

ment of minimally invasive anterior spinal surgery. Although most surgeons have moved to mini-open, or endoscopic retroperitoneal techniques, much of the technological development occurred in the laparoscopic field, and

the experience of the pioneers has established the efficacy and safety of such minimally invasive approaches, although questions remain about the cage fusion devices that have been inserted by this approach.

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