Anterior Access to the Lumbar Spine: Laparoscopic versus *Open*

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The purpose of this study is to investigate the potential advantages and complications of a minimally invasive laparoscopic approach for anterior spinal exposure as compared with the open technique and to quantify differences in operative time, blood loss, transfusion requirements, analgesia, and morbidity. A retrospective review was performed on all patients undergoing access for anterior spinal procedures. Demographics, operation-related variables, complications, and estimated cost were analyzed. Categorical data were analyzed using the Fisher's exact test and continuous variables were analyzed with the Mann-Whitney *U* test. We performed a total of 65 anterior spinal access procedures between February 1997 and April 2001 at our institution. Forty-five operations were performed at the L_5-S_1 level: 31 using transperitoneal laparoscopic techniques and 14 using an open minilaparotomy. Mean follow-up was 12 months (range 1–50). No significant differences between the groups were found when comparing analgesia requirements, time to resumption of oral intake, length of hospitalization, and complication rates. Statistical analysis showed that laparoscopic procedures were associated with shorter operating room times ($P = 0.08$) and less intraoperative blood loss ($P = 0.029$). The laparoscopic approach was estimated to cost $1,374 more than the open technique. Transperitoneal laparoscopic techniques for anterior spinal exposure are comparable to the standard open approach and offer no substantive advantages. The overall cost of laparoscopic spinal surgery is higher compared with conventional open procedures.

GENERAL, LAPAROSCOPIC, AND VASCULAR surgeons are frequently requested to provide exposure to the anterior spine for neurosurgical procedures. Anterior access to the spine can be achieved transperitoneally or via a retroperitoneal approach. The introduction of laparoscopic cholecystectomy by Dubois et al.[1] in 1989 revolutionized surgical thinking and provided the impetus for less invasive techniques that achieve the same end. Obenchain[2] first described laparoscopic spinal fusion in 1991. Although the feasibility and results of laparoscopic spinal fusion have been established in multiple series[3–6] proven advantages of this approach over standard open techniques are less well defined. The aim of this study is to compare laparoscopic and open anterior spinal exposure. The principal variables studied were operating room time, estimated blood loss, transfusion requirements, length of hospitalization, analgesia requirements, oral intake resumption, and significant morbidity. Cost estimates for these two different approaches were calculated.

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Materials and Methods

Our study group consisted of 65 anterior spinal fusion cases performed at Catholic Health Partners (Columbus-St. Joseph Hospital) in Chicago, IL from January 1997 to April 2001. Within this group open procedures were performed in 34 patients: thoracic fusions in seven, L_{1-4} in four, L_{4-5} in nine, and L_5-S_1 in 14. Laparoscopic L_5-S_1 fusions were performed in 31 patients (Group I; n = 31). To control for the variable of fusion level we compared the 31 patients in the laparoscopic group with the 14 patients in the open group (Group II; n = 14). The mean follow-up for the groups was 12 months (range, 1–50 months); one patient was lost to follow-up.

Patient demographics and indications for surgery are summarized in Table 1.

Open Procedure

Open access to the L_5-S_1 spine was achieved through a low midline incision between the umbilicus and the symphysis pubis. The abdominal wall fascia was incised in the midline and the bowel packed with warm laparotomy pads. The retroperitoneal space was

TABLE 1 *Patient Demographics*

	Group I: n = 31 (Laparoscopic)	Group II: n = 14 (Open)
Men/Women	17/14	6/8
Mean age	42	38
Weight (kg)	83.6	80.5
Previous abdominal surgery	12 (38%)	7 (50%)
Discogenic pain	3 (10%)	2 (15%)
Mechanical instability	28 (90%)	12 (85%)

entered with low-setting cautery to expose the L_5-S_1 disc space. The iliac vessels were retracted laterally after the left iliac vein was mobilized. Crossing vessels were ligated with titanium clips or silk ligatures. Once exposure was provided a team of neurosurgeons performed the anterior spinal fusion using threaded titanium interbody arthrodesis cages in 36 patients and placement of an artificial disc in nine patients.

Laparoscopic Procedure

An infraumbilical port was placed using the using the open technique. After insufflation of the abdomen with carbon dioxide and visual inspection of the pelvis and abdomen two 5-mm operating ports were placed under direct vision. With the patient in steep Trendelenberg position the sacral promontory was exposed and the retroperitoneal tissue and iliac vessels dissected off the disc space. A 15-mm suprapubic port was placed through which the team of neurosurgeons performed anterior spinal fusion using threaded titanium interbody arthrodesis cages.

Indications for open rather than laparoscopic spine exposure included: artificial disc protocol in patients, neurosurgeon's preference in three, and multiple previous laparotomies in two.

Measures of operating room time and estimated blood loss were recorded. The postoperative analgesia requirement was defined in our study as the number of days a patient required intravenous morphine sulfate via a self-controlled delivery system (patient-controlled analgesia). Other parameters assessed included number of days required for resumption of oral intake, length of hospital stay, and perioperative morbidities. Total hospital cost was estimated by incorporating standard operating room charges with average inpatient care fees.

Statistical Methods

Descriptive statistics are reported as medians and ranges. As there was no assumption of data normality the nonparametric Mann-Whitney *U* test was used to compare continuous variables. Fisher's exact test was used to compare categorical data.

Results

Data from 45 patients were collected and reviewed (Table 2). A significantly lower operative time was noted in Group I (laparoscopic) (median, 160 minutes; range, 110–330 minutes) compared with Group II (open) (median, 196 minutes; range, 135–460 minutes); $P = 0.008$. Similarly estimated blood loss was significantly lower in Group I (median, 200 cm^3; range, 50–2500 cm^3) *versus* Group II (median, 325 cm^3; range, 100–500 cm^3); $P = 0.029$. Only one patient required a blood transfusion; this was due to a left iliac vein injury during laparoscopic exposure.

Postoperative intravenous analgesics were needed for 2 days in both Group I (range, 1–6 days) and Group II (range, 1–5 days); $P =$ not significant. Median time to resumption of oral intake was one day in both groups. The duration of hospital stay was 3 days in each group; $P =$ not significant.

Group I morbidities included port site bleeding in one, retrograde ejaculation in two, ileus in three, and conversion to open procedure in four (for bladder perforation in one, bleeding in one, and inadequate visualization in two). Gastrointestinal ileus was defined as

TABLE 2. *Outcome Comparison*

	Present Report (2001)			Regan et al. (1999)[6]	
	Open	Laparoscopic	*P* Value	Open	Laparoscopic
Operative time (minutes)	196 (median)	160 (median)	0.008	136 (mean)	196 (mean)
Estimated blood loss (cm^3)	325 (median)	200 (median)	0.029	193 (mean)	143 (mean)
IV analgesia requirement (days): median	2	2	NS	Not reported	Not reported
Time to oral intake (days): median	1	1	NS	Not reported	Not reported
Hospital stay (days)	3 (median)	3 (median)	NS	3.4 (mean)	3.8 (mean)
Hospital cost ($) (estimated)	21,091	19,518		Not reported	Not reported

NS, not significant.

greater than 3 days to resumption of oral intake. Group II morbidities included ileus in five patients.

Hospital cost was estimated by tabulating the cost of supplies utilized during the operative procedure. The operating room fee was derived by multiplying the median length of time used for each technique by the 30-minute unit charge. Finally the hospital-bed cost was calculated by multiplying the median hospitalization time in each group by the daily bed cost. This method yielded a cost estimate of $20,591 for a laparoscopic endofusion and a cost of $19,217 for an open endofusion (Table 3).

Discussion

Potential advantages of a minimally invasive technique include less tissue trauma during dissection in the operative site, smaller scars, decreased need for postoperative analgesia, and decreased length of hospitalization. While attempting to achieve these goals a minimally invasive technique must obtain similar technical results and comparable complication rates when compared with its standard open counterpart. The feasibility, safety, and results of laparoscopic access for anterior spinal fusion have been clearly established.

The earliest series examining the laparoscopic approach to the anterior lumbar spine for the purpose of fusion were reported by Mathews et al.[3] and Zucherman et al.[4] in 1995. One of six patients (17%) required conversion to an open procedure in the Mathews series, whereas two of 17 patients (12%) were converted in the Zucherman study. Operative times varied widely in these two studies ranging from less than one

TABLE 3. *Computation of Hospital Cost (in U.S. Dollars)*

Supplies/Equipment	Cost
Common supplies (shared by both open and laparoscopic approach)	
General surgical supplies	135
Marcaine	37
Sutures	195
Neuro hypo unit	330
Foley catheter	27
C-arm drape	15
U-drape	14
Use of Cell Saver	1,266
Cell Saver supplies	295
Ray cages	7,704
Total common supplies	10,018
Approach-specific supplies	
Laparoscopic	
Camera	124
Electrocautery	219
Light source	87
Scope	123
Insufflation/suction	144
Fred defogger	20
Video system	46
Ports	644
Endostaplers	614
Endokittner	60
Endodissector	318
Endoshears	159
Endoretractor	200
Total laparoscopic	2,758
Open	
Bipolar cautery	19
Minor pack	543
OR neuro supplies	73
Total open	635

	Laparoscopic	Open
Totals		
Common supplies	10,018	10,018
Approach-specific supplies	2,758	635
OR: 30-minute block ($865/unit)	167′ × 865 = 4815	193′ × 865 = 5564
Hospital cost ($1,000/day)	× 3.5 days = 3000	× 3.3 days = 3000
Total (estimate)	20,591	19,217

OR, operating room.

hour to greater than 6 hours. Length of hospital stay averaged 4.2 days in the Mathews group and 2 days in the Zucherman group. Major complications focused on the neurosurgical aspect of the procedure, namely migration of the prosthesis, endplate fracture, and bone graft donor site infection; there was no mention of ileus, bowel injury, or bleeding.

As this technique evolved, Regan et al.[5] reported their experience in 1996 with their first 38 endofusion patients. Four of 34 patients (12%) required conversion to an open procedure: two secondary to poor visualization of the operative field and two because of bleeding. Operative time (3.6 hours) and length of hospital stay (3.6 days) were comparable to those in the studies of Mathews and Zucherman. Two iliac vein lacerations, thermal injury to the bowel, and lumbar disc herniation were reported as the major morbidities of the series.

Regan et al.[6] reviewed their experience with the same approach in an additional 58 patients in 1999. Operative time was essentially unchanged from their 1996 report, whereas average operative blood loss was lower (perhaps as a result of the absence of any major vessel injury). Length of hospital stay was marginally shorter in the 1999 *versus* the 1996 series (3.0 *vs* 3.6 days). Four reoperative procedures were included in this series. Major morbidities included bleeding in three patients (resulting in open conversions) and postoperative retrograde ejaculation in one patient.

The two most recent endofusion series to appear are those of Hawasli et al.[7] with 30 patients and Lieberman et al.[8] with 47 patients. Only one patient in the Hawasli et al.[7] group (3%) and four patients in the Lieberman et al.[8] (9%) required open conversion. This is slightly higher than our reported conversion rate of 12 per cent. As in the Hawasli et al.[7] group we experienced one bladder perforation that required open repair and we had one iliac vein injury as in the Lieberman et al.[8] group. Estimates of operative blood loss in our laparoscopic group were greater than in either series (Hawasli et al.,[7] 75 cm^3 *vs* Lieberman et al.,[8] 105 cm^3 *vs* present study, 200 cm^3), although only the iliac vein injury patient in our group required a blood transfusion. The disparity of estimates of intraoperative blood loss might be due to differing protocols used by investigators. At our institution the anesthesia service has the responsibility (in consultation with the surgeon) to determine "operative" blood loss.

The median operative time in our series was 2.7 hours as compared with 2.3 hours in the Hawasli et al.[7] group and one to 6 hours in the Lieberman et al.[8] group. Our length of hospital stay was 3 days, which is slightly longer than in the Hawasli group but shorter than the 5 days reported in the Lieberman group. Procedure-specific complications due to disruption of the hypogastric sympathetic nerve plexus include retro-/anejaculation and the "warm leg" syndrome. Whereas we reported no cases of the "warm leg" phenomenon Lieberman et al.[8] found three patients with this postoperative morbidity; Hawasli et al.[7] did not reference this parameter.

As endofusion patients become younger and greater attention is paid to pre- *versus* postoperative sexual function the incidence of ejaculatory dysfunction has become better acknowledged. Although only two patients in our group and two in the Lieberman group experienced significant sexual dysfunction subtle changes are often detected by thorough questioning. Decreases in the volume and force of the ejaculate are two of the most common complaints of male postoperative endofusion patients. The incidence of retrograde ejaculation reported in the open approach to spinal fusion is 10 to 15 per cent with a greater risk in patients undergoing multilevel fusions. Although this problem is generally self-limited postoperative anxiety can be greatly alleviated by a thorough discussion with the patient before operation and sometimes by prolonged supportive follow-up in the postoperative months.

Two series have compared laparoscopic and open spinal surgery. Katkhouda et al.[9] in 1999 compared six patients undergoing laparoscopic multiple-level spinal exposure with 12 patients operated upon through an open incision. They found significant differences in operating room time (312 minutes in the laparoscopic group *vs* 168 minutes in the open group), hospital stay (10 days for the laparoscopic group *vs* 7 days for the open group), and morbidity (83% in the laparoscopic group *vs* 17% in the open group). They concluded that for multiple-level spinal surgery an open approach was the procedure of choice. Regan et al.[6] (also in 1999) reported the experience of eight spine centers with laparoscopic spinal fusion. Comparison of 215 patients undergoing laparoscopic single-level anterior spinal fusion with 305 procedures done via an open approach revealed less blood loss and an increased operative time for the laparoscopic group. The investigators concluded that the laparoscopic procedure is safe and effective when compared with the open technique. Neither of these studies demonstrated an overwhelming advantage over the minimally invasive approach.

It is interesting to note that open procedures at our institution took more than 30 minutes longer than their laparoscopic counterparts, whereas in the Regan et al.[6] series open endofusion procedures were actually 60 minutes shorter than those done laparoscopically. This is perhaps best explained by the fact that one surgeon performed the majority of laparoscopic fusion procedures at our institution, whereas several different sur-

geons were involved with the open approach. Our reported operative morbidity rates of 32 per cent in the laparoscopic group and 35 per cent in the open group are almost twice those reported by Regan et al.[6] (17% and 14%, respectively). This can be attributed to our inclusion of postoperative gastrointestinal ileus as a morbidity. Our conversion rate of 12 per cent is comparable to the 10 per cent rate reported by Regan et al.[6]

Little doubt exists that the laparoscopic approach to the L_5-S_1 spine for fusion is a safe procedure in experienced hands. Quantification of hospital/procedure cost for comparative purposes with other investigators is fraught with inconsistencies depending on hospital policy and surgeon preference. Using the median values of our operative parameters we sought to compare the cost of a "standard" open *versus* a "standard" laparoscopic endofusion (Table 3). By making several inherent assumptions that are certainly open to various criticisms we found that laparoscopic endofusion cost approximately $1,400 more than its open laparotomy counterpart despite the additional 30-minute operating room time cost in the open group. Reusable laparoscopic instruments might decrease the cost of this approach, but consideration needs to be given up-front purchase price of nondisposable instruments along with a prorated fee for maintenance and resterilization/repackaging.

In summary laparoscopic endofusion is an established and accepted technique. Notwithstanding issues of cosmesis—which might be dampened in the laparoscopic group by the ultimate need for a suprapubic minilaparotomy—open exposure is comparable in terms of outcome analyses and overall cost. We found a minimal learning curve for the laparoscopic procedure given experience derived from the variety of other laparoscopic procedures that are routinely performed. The role of laparoscopic endofusion in our institution remains driven largely by surgeon preference rather than efficacy or cost.

REFERENCES

1. Dubois F, Berthelot G, Levard H. Cholecystectomy by coelioscopy [French]. Presse Med 1989;18:980–2.

2. Obenchain TG. Laparoscopic lumbar discectomy· Case report. J Laparoendosc Surg 1991;1 145–9.

3. Mathews HH, Evans MT, Molligan HJ, Long BH. Laparoscopic discectomy with anterior lumbar interbody fusion: A preliminary review. Spine 1995;20:1797–802.

4. Zucherman JF, Zdeblick TA, Bailey SA, et al. Instrumented laparoscopic spinal fusion: Preliminary results. Spine 1995;20: 2029–34.

5. Regan JJ, McAfee PC, Guyer RD, Aronoff RJ. Laparoscopic approach to L_{4-5} interbody fusion using BAK cages: Experience in the first 58 cases. Surg Laparosc Endosc 1996;6:459–68.

6. Regan JJ, Aronoff RJ, Ohnmeiss DD, Sengupta DK. Laparoscopic fusion of the lumbar spine: minimally invasive spine surgery· A prospective multicenter study evaluating open and laparoscopic lumbar fusion. Spine 1999;24;2171–4.

7 Hawasli A, Thusay M, Elskens DP, et al. Laparoscopic anterior lumbar fusion. J Laparoendosc Adv Surg Tech A 2000;10: 21–5.

8. Lieberman IH, Willsher PC, Litwin DE, et al. Transperitoneal laparoscopic exposure for lumbar interbody fusion. Spine 2000;25:509–14.

9. Katkhouda N, Campos GM, Mavor E, et al. Is laparoscopic approach to lumbar spine fusion worthwhile? Am J Surg 1999; 178:458–61.

DISCUSSION

LYNN R. BUCKNER, M.D. (Decatur AL): This is a retrospective review comparing open intraperitoneal and laparoscopic exposures for one level, L_5-S_1, anterior interbody spinal fusion. Over 4 years 31 patients had laparoscopic exposure to the anterior spine at the L_5-S_1 level with a 10 per cent conversion to an open procedure. Fourteen patients during this same period underwent open exposure of this same level. These two exposures were compared using operative times, blood loss, analgesia use, and ileus. A cost analysis was also performed. It was determined that there was no difference in these exposures except the blood loss was lower and the cost higher for the laparoscopic exposure. The authors concluded that there was no clear advantage of exposing the L_{4-5} spine laparoscopically when compared to the open approach.

Laparoscopically exposing the L_{4-5} level or multiple lumbar spine levels has not reliably been shown to be safe because of injuries to the left iliac vein and the difficulty in mobilizing the iliac vessels to clearly expose these levels. It has been shown to be safe and efficient to laparoscopically expose the L_5-S_1 level because this is usually done between the iliac vessels and requires little mobilization of these large vessels. It is perceived and shown by some that laparoscopic L_5-S_1 anterior interbody fusion allows shorter hospital stays, decreased problems with ileus, and quicker returns to normal outpatient activity. But no prospective, randomized study comparing these two approaches has proven the superiority of the laparoscopic approach. In outpatient follow-up of these patients did those who underwent laparoscopic exposure return to work sooner? If there is no advantage to the laparoscopic approach do you still offer patients this procedure at your institution? Do you foresee a benefit to the laparoscopic approach as more procedures are performed and instrumentation improves?

A left iliac vein injury and bladder tear were complications of the laparoscopic approach in this review. Did these occur early in the study and what precautions or interventions do you take preoperatively to minimize complications? Who discusses operative risks with the patient preoperatively? Do the spine surgeon and the laparoscopist see the patient independently? Is the general

surgeon present throughout the laparoscopic and open procedures?

Among our spine surgeons there appears to be a shift recently back to the posterior approach for lumbar fusion. It has been shown that there can be a 30 per cent incidence of disunion and subsidence at one to two years after anterior interbody fusion. Therefore do you feel that the community general surgeon needs to be getting involved with these laparoscopic approaches to the anterior spine?

HÉRON E. RODRÍGUEZ, M.D. (Closing Discussion): Assessing a patient's time to return to work after spinal fusion is a complex issue. Greater than half of these patients are not working at the time of surgery and a large percentage are involved in workman's compensation litigation due to their injuries. We tried to analyze these parameters but unfortunately were not able to generate meaningful data. I doubt that the type of approach will appreciably change this situation.

The second question was about how we currently perform spinal fusion procedures. The Chicago Institute of Neurosurgery at Columbus Hospital is a tertiary care referral center. Laparoscopic spinal fusion is offered due to patient demand. In my current situation at Northwestern University in the Department of Vascular Surgery we perform all spinal exposures via an "open" retroperitoneal approach. Do I see a benefit from the "open" retroperitoneal *versus* transperitoneal approach? In my experience both are equivalent. We have shown that laparoscopy is safe and feasible; the question now remains, is it truly superior to other standard procedures?

Earlier today Dr. Gadacz mused about treatment protocol changes for standard procedures with the advent of the laparoscopic era. We learned that "open" spinal fusion patients can and should start eating and ambulating earlier in their postoperative courses. Is there a learning curve for minilaparotomy? Yes, but I do not believe it is a difficult procedure to master. The key is to recognize the presence of and ligate the branches of the iliac vein before retracting the vessel. Preoperative MRI/MRA delineates the exact location of the bifurcation of the aorta and vena cava. While this is expected to be at the level of L4 there is an excellent poster at this meeting demonstrating the anatomic variability of this region. Also the iliac vein can veer over the midline. This is helpful to know preoperatively to plan operative strategy.

Do we see these patients preoperatively? The answer is yes. During the preoperative visit we discuss the procedure and potential complications—gastrointestinal, vascular, and neurological (especially retrograde ejaculation). The patients are again evaluated in the office after the procedure to assess these systems.

Should general surgeons be trained to do retroperitoneal exposure? The key to this question is comfort level of the practitioner with managing complications—namely injury to the vena cava. I think a well-trained general surgeon should be able to perform either a transperitoneal or retroperitoneal approach to the spine via a minilaparotomy. While we have not compared the results of these two procedures I think a study would provide useful data to guide our future practice.