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Gasless endoscopic anterior lumbar interbody fusion utilizing the B.E.R.G. approach

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Abstract
Background: Several authors have reported success using a gas-mediated transperitoneal approach for lumbar interbody fusion. However, this approach has not been shown to reliably and predictably address segments above L4–5.
Methods: The B.E.R.G. approach was attempted in 202 patients who required anterior lumbar interbody fusion (ALIF). Of those, 168 were completed successfully without conversion to an open procedure. The anterior retroperitoneal approach required no gas insufflation. The gasless environment allowed for the use of standard anterior instrumentation and a variety of fusion grafts and devices.
Results: Mean hospital stay was 1.95 days, with 73% of patients discharged in <47 h following surgery. Clinical results from the first 50 patients, with a minimum 2-year follow-up, include a 92% fusion rate and 78% of patients reporting significant pain relief of greater than 50%.
Conclusions: The B.E.R.G. approach offers significant technical advantages over the standard gas-mediated transperitoneal approach for ALIF. The clinical results are similar to those reported for open approaches and the gas-mediated transperitoneal approach.

Key words: Anterior interbody fusion — Balloon dissection — Gasless endoscopy — Lumbar spine — Spine

Laparoscopic anterior discectomy was first described by Obenchain [10] in 1991. Since that time, a number of investigators have adopted a gas-mediated transperitoneal laparoscopic approach to anterior lumbar discectomy and fusion [7, 9–17]. Preliminary clinical results reported with this technique are promising. However, this approach to the lumbar spine has many technical drawbacks.

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The transperitoneal laparoscopic approach is limited to access of L5–S1. In some cases, L4–5 can be addressed, but not on a reliable and predictable basis. The environment of a gas-mediated transperitoneal laparoscopic technique dictates a spherical, valved-port approach. The benefits of this approach include the control of bowel motion, tamponading of small vessels, and adequate access for soft tissue instruments. Although the minimally invasive approach to spinal surgery yields several benefits, the disadvantages associated with a gas environment may severely limit the performance of spinal surgery.

Carbon dioxide gas insufflation can cause significant physiologic and hemodynamic changes during the surgical procedure [3]. The gas environment does not allow for large tissue removal or large instrument access to the spinal column. Suction to remove blood is limited because suction devices often remove CO_2 from the abdomen faster than the insufflator can deliver it, leading to loss of exposure within the operating cavity. In addition, when valved ports are used, the instrument fulcrums are too far away from the operative field, making spinal surgery inefficient. The surgeon is significantly restricted with regard to disc and bony removal as well as choice of instrumentation.

McAfee et al. [8] have described the use of a gasless lateral retroperitoneal approach, with an emphasis on the lateral insertion of the BAK device (Sulzer Spine-Tech, Minneapolis, MN, USA). The use of the lateral retroperitoneal approach allows for access to the upper levels of the lumbar spine. However, the surgical team is limited to the lateral insertion of screw-in cages or bone graft for fusion—techniques that are not desirable in many cases. In our experience, the lateral retroperitoneal approach utilized by McAfee et al. leads to an unusually high incidence of radiculopathy and neuropraxic injury (80%). We consequently abandoned the approach after five cases. However, McAfee et al. did not report any such complications in their study, even though 15 of their 18 patients underwent anterior fusion.

The B.E.R.G. (balloon-assisted endoscopic retroperito-

Table 1. Levels of fusion/instrumentation

Successful cases						Converted cases					
Single-level		Double-level		Triple-level		Single-level		Double-level		Triple-level	
L2–3	1	L2–4	3	L3–S1	5	L2–3	0	L2–4	0	L2–5	1
L3–4	4	L3–5	5			L3–4	2	L3–5	3		
L4–5	43	L4–S1	51			L4–5	8	L4–S1	12		
L5–S1	56					L5–S1	8				

neal gasless) method eliminates the problems associated with a gas-mediated approach to the lumbar spine. The B.E.R.G. technique is completely gasless, and it is a true retroperitoneal approach to the anterior spine (as opposed to a lateral retroperitoneal approach). First, a balloon dissection of the retroperitoneum is performed under direct vision. Next, a fan retractor is attached to a mechanical lifting arm. They are used in tandem to lift the abdominal wall, replacing the need for CO_2 distention. A long-handled balloon retractor can then be inserted to internally retract the peritoneal contents, allowing direct anterior or lateral access to the lumbar vertebral bodies. The gasless environment does not limit the size or number of standard anterior instruments or implants that may be utilized. Yet the potential for physiologic or hemodynamic changes and the suction problems caused by the use of gas are eliminated.

Methods

The B.E.R.G. approach was attempted in 202 patients scheduled for anterior interbody fusion at one or more levels over the course of 2 1/2 years. All but eight of them needed supplemental posterior fixation and/or fusion. Of these 202, 168 cases (83 male, 85 female) were completed successfully without conversion to an open procedure. The primary diagnoses of the successful 168 cases were as follows: internal disc disruption verified by positive discography (87), failed laminectomy (24), spondylolisthesis (23), degenerative disc disease (22), spinal stenosis (seven), severe disc herniation (two), pseudarthrosis (two), and aseptic discitis (one). Reasons for conversion in the remaining cases included vessel laceration (15), retroperitoneal scarring (eight), obesity (five), nerve lying on disc space (two), inadequate bowel retraction (two), and thin peritoneum (two). All patients had signed an informed consent form stating that an open anterior retroperitoneal approach would be utilized if the B.E.R.G. approach was unsuccessful.

Mean age in this group was 45 years, with a range of 23–74 years. In all, 101 patients had had no prior lumbar surgery. A total of 125 patients had worked within 12 months prior to surgery. All but eight patients were also instrumented posteriorly, 128 with translaminar fixation and 32 with transpedicular fixation, with or without posterolateral fusion. Of the 160 combined procedures, 142 were performed on the same day. There were 104 single-level, 59 double-level, and five triple-level fusions (Table 1). Several different bone grafting and/or fusion devices were employed anteriorly (Table 2).

Table 2. Types of graft/fusion device

Device	No. of cases
Femoral ring allograft/coralline hydroxyapatite	89
AO Titanium Interbody Spacer (TIS)/coralline hydroxyapatite core	37
AO Syn Cage/iliac crest autograft	21
Femoral ring allograft/local autograft	12
BAK/iliac crest autograft	6
Ray Cage/iliac crest autograft	2
Harms (MOSS) Cage/iliac crest autograft	1

Operative technique

The procedure is executed with one spinal surgeon, one vascular/general surgeon, and one endoscopically trained technician (Fig. 1). The patient is placed in the supine position. Following administration of general anesthesia, the patient is draped and prepped in standard fashion, and preoperative antibiotics are given. Fluoroscopy is used to find the landmarks of the appropriate lumbar level. The skin is marked to identify the level and angle of the pathological disc interspace(s). These marks are drawn on the lateral aspect of the left abdomen, indicating the angles of the disc spaces to be addressed.

A transverse 20-mm left flank incision is made ~1 cm above the left iliac crest in the mid-axillary line (Fig. 2). Under direct vision, the dissection is taken down through the external oblique, internal oblique, and transversus muscles to the preperitoneal fat layer using a clear-ended endoscopic dissecting port. The retroperitoneal space is then gently insufflated with a bulb syringe and digitally dissected into the iliac fossa to allow for balloon insertion. An uninflated elliptical-shaped preperitoneal balloon is advanced through the incision until the entire balloon is within the retroperitoneal space.

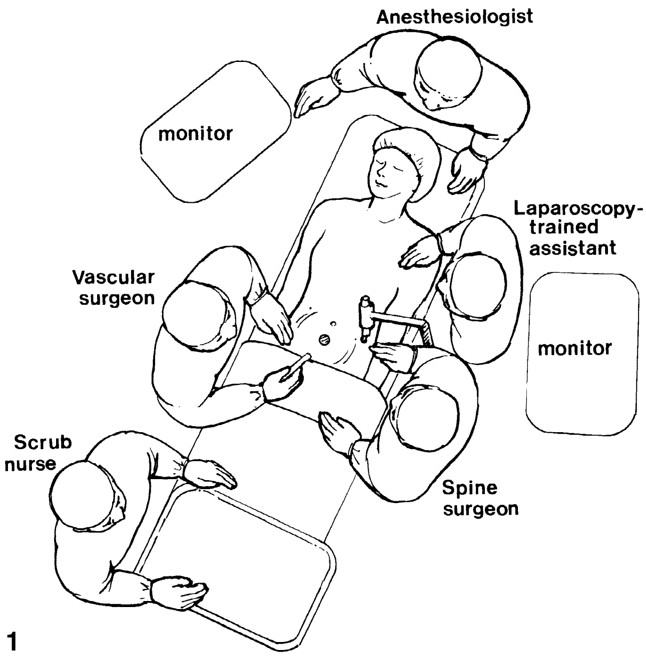
A 0° angle endoscope is placed through the lumen of the dissection cannula, and the balloon is expanded to a volume of ~1 L. The endoscope is directed toward the anterior abdominal wall. This position allows the identification of the peritoneal reflection on the anterior abdominal wall, at the rectus sheath, above and below the line of Douglas. The peritoneal reflection is used as a landmark for the anterior working port. The anterior working port is located lateral to the peritoneal reflection on the rectus sheath. This port is formed at a level determined by the preoperative markings on the abdomen, which correspond to the interspace angulation.

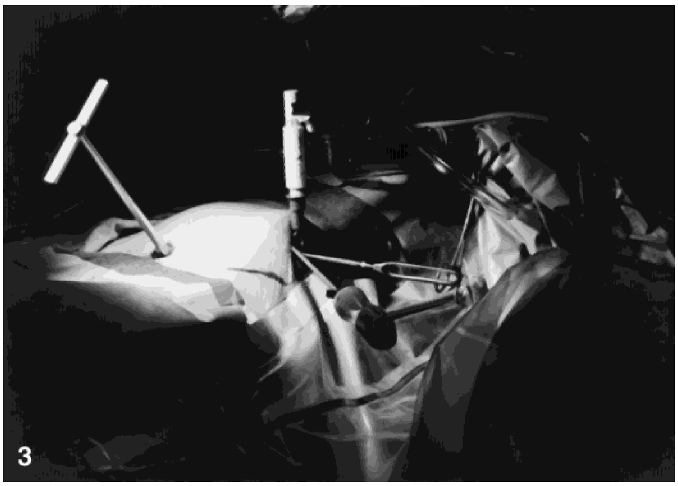
A 2–3-cm paramedian incision is made through the anterior abdominal wall and carried down through the fascia. The incision is made lateral to the peritoneal reflection, taking great care to avoid the peritoneal sac. This procedure creates the anterior working/retraction port. The balloon is removed after a 1-cm malleable retractor is placed between the two ports under direct endoscopic vision. Once the retroperitoneal space has been mobilized, the next goal is the retraction of the abdominal wall.

There are three levels of retraction necessary to access the anterior lumbar spine. The first level is distraction of the anterior abdominal wall. This is accomplished by the insertion of a fan retractor into the initial flank port. The fan retractor is expanded under direct endoscopic vision. Once expanded, the fan retractor is attached to a mechanical lifting arm. The abdominal wall is thereby elevated, creating the retroperitoneal space and obviating the need for gas (Fig. 3). A flexible nonvalved port, which is used for lateral visualization and retraction, is placed directly below the legs of the fan retractor to provide a clear path for the endoscope.

The second level of retraction is necessary to displace the peritoneal contents past the midline, thus providing access to the lumbar spine and vascular anatomy. A long retractor with an inflatable end is inserted through the newly created lateral working port in the initial left flank incision to push the peritoneal sac and intraabdominal contents aside, creating the working space (Fig. 4).

The third level of retraction in this approach is vascular. Following establishment of the operative cavity, the psoas muscle and vascular anatomy are used as reference landmarks. The psoas muscle is bluntly dissected to expose the pathologic disc space(s). The L5–S1 vascular re-





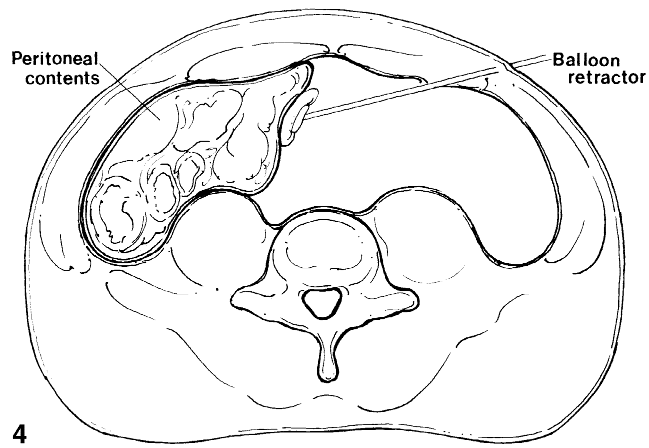


Fig. 1. Operating room setup and patient positioning for the B.E.R.G. approach.

Fig. 2. The first incision is made in the mid-axillary line ~1 cm above the iliac crest.

Fig. 3. The fan retractor and mechanical lifting arm are used in tandem to distend the abdominal wall, creating the operative space. The anterior working port is in the foreground.

Fig. 4. The long-handled retractor is used to retract the peritoneal sac, thereby exposing the anterior lumbar spine.

traction begins with identification of the right iliac vein. An AO anterior vascular retractor is used to retract the fascia and presacral veins, thereby exposing the anterior aspect of the L5–S1 interspace. A standard vein retractor is passed through the visualization/retraction port. It is used to retract the iliac vein laterally. Next, the presacral veins are ligated or cauterized with bipolar cautery. Great care must be taken in dissecting the anterior soft tissues in order to maintain the integrity of the presacral plexus.

The L4–5 exposure is more complex. It begins by utilizing the AO anterior vessel retractor to displace the vena cava or left iliac vein and place it on tension. Once the iliolumbar vein is identified, it is ligated using a right-angled clip and corporeal knot tying. The knot is generally reinforced with two specific ligatures. The posterior aspect of the iliolumbar vein can be handled with vascular clips. After litgation of the iliolumbar vein, gentle, soft dissection is used to retract the left iliac vein, exposing the L4–5 interspace past the midline. The vascular retraction for L3–4 is performed in a similar way, but it does not require ligation of the iliolumbar vein.

Following psoas dissection and vessel retraction, a spinal needle is placed into the pathologic disc(s), and fluoroscopy is employed to confirm the operative level. The anterior working port allows for both vascular retraction and the introduction of standard spinal instruments, such as dissectors, rongeurs, curettes, and end plate cutters (Fig. 3).

We used the B.E.R.G. approach to perform anterior lumbar interbody fusion (ALIF). The technique for ALIF is essentially identical to the open anterior retroperitoneal approach. Discectomy begins by incising the anterior annulus with a long-handled scalpel both cranially and caudally as well as left and right. End plate cutters, rongeurs, and curettes are introduced and manipulated through the anterior working port. Once the disc is removed, the surgical team has several options for fusion—anatomic cage, screw-in cage, allograft, or autograft (Table 2). After the allograft, disc prosthesis, or cage is placed, the option of AO anterior buttress plate fixation is possible. Thereafter, the implant position is confirmed through fluoroscopy.

Upon satisfactory imaging, the retroperitoneum is inspected, and the three levels of retraction are removed. The incisions are closed in a standard fashion, and the patient can be mobilized the same day. Rehabilitation begins at 2 weeks, and the patient is advanced with activities as tolerated.

Results

Technical results

Mean operative time for a single-level fusion was 101 min (range, 45–225); for a double-level fusion, it was 129 min (range, 63–210). We attempted the B.E.R.G. approach in 202 patients, of whom 168 were completed successfully while 34 were converted to open anterior retroperitoneal procedures. Although our total conversion rate was 16.8%, the rate decreased dramatically over time. For the first 101 total cases, the rate of conversion to open anterior surgery was 24%; but for the second 101 total cases, the rate was reduced to 10%. As the learning curve decreased, we were able to overcome complications that would have forced a conversion early in our experience with the new approach. Perioperatively, six vessel lacerations were repaired endoscopically without sequelae. There was also one ruptured diverticulum. There were no other perioperative complications.

Of the 142 patients undergoing either anteroposterior surgery on the same day or stand-alone ALIF, mean hospital stay was 1.95 days, with 73% of patients discharged within 47 hs. Mean endoscopic blood loss was 201 cc (range, 25–4,000). We encountered one retrograde ejaculation and one deep vein thrombosis (DVT) in this series as well as two postoperative foot drops, which were secondary to the posterior procedures.

Clinical results

The first 50 patients in this series have a minimum follow-up of 24 months and a maximum of 36 months. Two patients had their posterior hardware removed. One was solidly fused, the other had a pseudarthrosis and was redone posteriorly. There was one femoral ring migration (Fig. 5) and one titanium interbody spacer (TIS) migration of >5mm. Using standard radiographic criteria for anterior interbody fusion—i.e., no motion on flexion/extension radiographs and absence of halo—independent evaluation showed that 46 of 50 patients (92%) were solidly fused at 24 months.

Mean pain decreased 63%, with 78% of patients reporting significant pain relief of ≥50% (Figs. 6, 7). Of the 43 patients in this group who were working prior to surgery, 51% returned to work. Of those, 69% of privately insured patients returned to work at a mean of 3.8 months postop, while 41% of Workman's Compensation patients returned at a mean of 5.7 months postop.

Discussion

Laparoscopic discectomy and fusion was originally developed to decrease the morbidity of open procedures, reduce hospital stays, accelerate rehabilitation, and help secure an expeditious return of the patient to the work force. The standard gas-mediated transperitoneal laparoscopic approach to lumbar discectomy and fusion has partially achieved these goals. However, the problems associated with this approach severely limit the potential for this technique to be used on a widespread basis for a variety of lumbar pathologies.

In contrast, the B.E.R.G. technique eliminates the problems associated with gas-insufflated procedures and the transperitoneal laparoscopic approach. By using a direct anterior retroperitoneal approach and a long inflatable retractor, the peritoneum itself is used as a physiologic bowel retractor, which saves time and minimizes visceral trauma. Only two ports are used, as opposed to the four to six required for the transperitoneal approach (Fig. 8). Reliable and predictable direct anterior access from L2 to the sacrum is achieved readily. Suction and subsequent maintenance of the pneumoperitoneum is not an issue with this method. Perhaps the greatest benefit of the B.E.R.G. approach is the fact that in a nonpressurized environment standard anterior instrumentation and implants can be used because there are no valved ports. The access sites can also be modified to accommodate large instruments or implants. This flexibility greatly reduces the endoscopic learning curve.

Experimentation with a variety of grafts and devices for anterior column support was part of our formulation of this new technology. Our access to certain anatomic cages (the TIS cage and the SynCage) was limited when they were officially designated as FDA investigational devices during the initial series and thus could no longer be utilized as custom devices. Thereafter, we relied extensively on bone bank femoral ring allograft. The choice of filler for the femoral rings (autograft vs coralline hydroxyapatite) was somewhat arbitrary in nature, depending upon the patient's bone stock and whether bone had already been harvested for the posterior procedure. Screw-in cages, such as the BAK and the Ray Cage, were utilized sparingly because it is our belief that screw-in cages and stand-alone anterior fusions are narrowly indicated for lumbar spinal fusion.

Admittedly, our conversion rate of 16.8% is high. The high rate can be attributed in part to the learning curve of the approach, which was combined with the endoscopic learning curve of several members of our group. As the surgical team became more adept at overcoming complications endoscopically, the rate dropped dramatically.

Although morbid obesity and prior abdominal surgery are normally relative contraindications to endoscopic surgery, we did not find them to be significant contraindications to the B.E.R.G. approach. Although five patients were converted to an open procedure because of obesity, these conversions occurred early in our experience, before longer retractors were developed. Since that time, 21 patients with mild to morbid obesity have been treated successfully. These patients had a weigh-to-height ratio of ≥3.0 lb/in, with a maximum of 4.39 lb/in.

This series also included seven successful revisions of previous retroperitoneal approaches.

At first, vessel lacerations proved to be a serious complication of this approach. Fifteen cases were converted to open procedures due to this type of injury. At the beginning of our learning curve, a vessel laceration was considered to require automatic conversion to an open procedure. Successful suturing of vessel lacerations endoscopically can be a technical challenge. However, once the surgical team be-

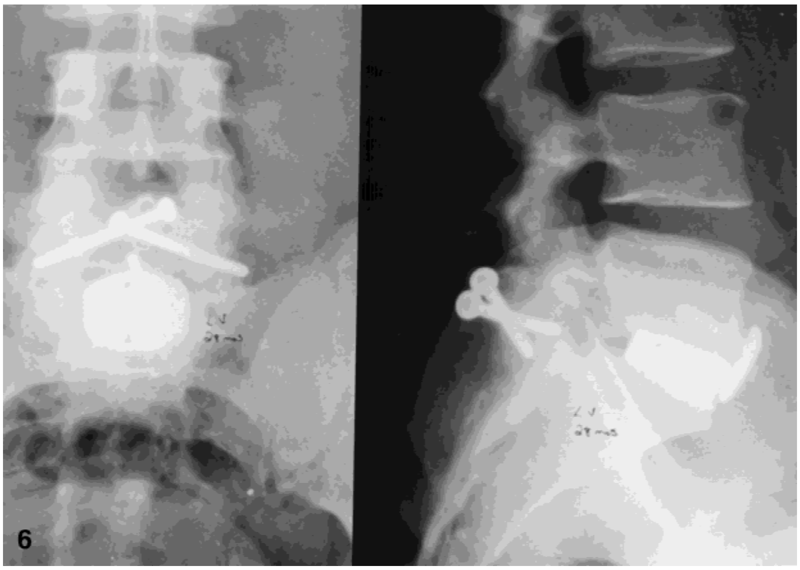


Fig. 5. A/P and lateral radiographs at 26 months postop of a 40-year-old woman. The patient presented with degenerative disc disease at L4–5 and L5–S1. She was fused with a femoral ring allograft anteriorly. At 3 months postop, the buttress plate pulled out, with subsequent migration of the femoral ring at L5–S1. The graft later fused solidly. The patient returned to work at 3 months postop and enjoyed a 70% reduction in her pain.

Fig. 6. A/P and lateral radiographs at 24 months postop of a 43-year-old male patient presenting with degenerative disc disease at L5–S1. An AO Titanium Interbody Spacer (TIS) custom device was used for fusion. Total operative time was 70 min. The patient returned to work at 3 months postop and remains totally asymptomatic.

Fig. 7. A Preoperative CT scan following discography of a 43-year-old male patient with internal disc disruption of L2–3 and L3–4. AO Syn Cages (a custom device) were used for ALIF. **B** A/P and lateral radiographs at 25 months postop. The translaminar screws at L3–4 were removed at 12 months postop due to possible nerve root irritation. The patient was found to be fused at the time, and his pain was reduced by 70% over its preoperative level.

came proficient at their endoscopic repair, no further conversions occurred in our series.

Seventy-three percent of patients treated successfully with the B.E.R.G. approach, with anteroposterior surgery on the same day or stand-alone ALIF, were discharged within 47 h (mean, 1.95 days). By comparison, Regan et al. [13] reported a mean hospital stay of 3.67 days for an initial series of 30 patients undergoing successful anterior interbody fusion of L4–5 and/or L5–S1 through a transperitoneal laparoscopic approach. In a second series of 240 patients described by Regan et al. [12], the mean hospital stay was 3.3 days. Olsen et al. [11] documented a mean hospital stay of 3.00 days for 75 patients undergoing transperitoneal laparoscopic anterior interbody fusion of L5–S1. In a study similar to the initial series, published by Regan et al., Zucherman et al. [17] reported a mean hospital stay of 2.00 days for their initial single-stage series of 17 patients. In 1997, Henry et al. [2] recorded a mean hospital stay of 4.4 days in 51 patients undergoing a gas-mediated transperitoneal approach. They also described 25 patients who were

Fig. 8. The two scars left by the B.E.R.G. incisions at 12 months postop.

treated via the B.E.R.G. approach for anterior interbody fusion; the mean hospital stay for that group was 5.7 days. In a study by McAfee et al. on the lateral retroperitoneal approach [8], the mean hospital stay was 2.9 days.

Zucherman et al. also reported an operative time range of 4.5–7 h for a double-level fusion with the BAK device vs a mean operative time in this study of 129 min and a range of 63–210 min for a double-level procedure. Our mean operative time for single-level fusion of 101 min compares favorably with Zucherman's range of 80 min to 6 h, Olsen's mean of 192 min, Henry's mean of 117 min, and Regan's means of 218 min and 201 min, respectively. Henry's mean operative time for the B.E.R.G. technique was 150 min. McAfee's mean operative time for the lateral retroperitoneal approach was 115 min for single-level fusion.

Using an open retroperitoneal approach for the BAK device, Kuslich et al. [5] reported a 91% fusion rate in 247 patients, as well as 85% of patients with pain improvement at 24 months postop. Liljenqvist et al. [6] reported a 95.2% fusion rate for open anteroposterior lumbar fusion with femoral cortical allograft and an 82.4% satisfaction rate among all patients. In a 1996 study by Gertzbein et al. [1], a fusion rate of 97% was achieved with open circumferential fusion using transpedicular fixation posteriorly and a femoral ring allograft for ALIF. Gertzbein et al. also stated that 77% of patients had a "good clinical outcome." In 1990, a study by Kozak and O'Brien [4] of open global fusion resulted in fusion rates in excess of 90% for one or two levels and 80% of patients with an acceptable clinical outcome. Our fusion rate of 92% compares favorably with all four studies. Furthermore, 78% of patients in this series had a good clinical outcome at 24 months postop.

Our return-to-work rates were lower than those reported by Kuslich et al.—51% vs 78%. The Kuslich study was prospective in nature and included carefully selected patients with degenerative disc disease who had received an FDA investigational device exemption. Our series is retrospective and encompasses a much broader range of lumbar pathologies.

Published long-term clinical results for transperitoneal laparoscopic ALIF are scarce. The initial study by Regan et al. found a fusion rate of 88% for 34 patients treated only for L4–5 and/or L5–S1. Their second study did not examine fusion rates. Henry et al.'s study also did not include fusion rates or clinical outcomes. Olsen et al., again using a transperitoneal gas-mediated approach and addressing only L5–S1, did not report a solid fusion rate. However, in the 23 patients who reached 2-year follow-up, mean pain decreased 74% and 78% of patients enjoyed "significant improvement." McAfee et al. achieved a 100% fusion rate using the lateral retroperitoneal approach in 15 patients.

In conclusion, we believe that the B.E.R.G. approach to the lumbar spine is an excellent contribution to minimally invasive spinal surgery from a technical standpoint. Once the endoscopic learning curve has been mastered, the benefits of using standard instrumentation and implants in a gasless environment rather than a gas-mediated approach cannot be overstated. Reliable access from L2 to the sacrum is also an advantage that the standard transperitoneal gas-mediated approach does not offer the spinal surgeon. Although a lateral retroperitoneal approach—such as the one described by McAfee et al.—eliminates some of the problems of a gas environment, in most cases the lateral fusion technique is not as desirable as traditional interbody fusion. Clinical results at 2 years are similar to those achieved with open stand-alone ALIF, open global fusion, and ALIF of L4–5 and/or L5–S1 through the transperitoneal approach. A logical extension of this approach to include vertebrectomy, metastatic tumor management, and deformity correction is warranted.

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