The history of modern spinal surgery dates back almost 100 years. Many of the first applications of spinal surgery were directed toward treating infections of the spinal column. Traditionally, these surgeries are performed with open anterior and posterior approaches to the spine, requiring large incisions for adequate exposure. In the early 1990s, a new field was on the horizon, which provided more direct access to the regions of pathology. The first reports of minimally invasive spine surgery appeared in 1991 when Obenchain described a laparoscopic lumbar discectomy. Since that time, the art of minimally invasive spine surgery has become more refined and more popular. The advantages include less tissue disruption, less postoperative pain, shorter hospital stays, and faster return to normal activities.

The aim of this study is to evaluate the morbidity of the transpsoas approach. This approach differs from the previous retroperitoneal approaches in that the access to the spine is directly through the iliopsoas muscle via a much shorter incision, versus a larger exposure and subsequent retraction of the psoas in the posterior direction.

**Methods.** A nonrandomized, prospective study utilizing a self-reported patient questionnaire was conducted between January 2006 and June 2008 at Northwestern University. Data were collected in 53 patients with a follow-up period ranging from 6 months to 3.5 years. Only 2 patients were lost to follow-up.

**Results.** Thirty-six percent (19 of 53) of patients reported subjective hip flexor weakness, 25% (13 of 53) anterior thigh numbness, and 23% (12 of 53) anterior thigh pain. However, 84% of the 19 patients reported complete resolution of their subjective hip flexor weakness by 6 months, and most experienced improved strength by 8 weeks. Of those reporting anterior thigh numbness and pain, 69% and 75% improved to their baseline function by the 6-month follow-up evaluations, respectively. All patients with self-reported subjective hip flexor weakness underwent examinations during subsequent clinic visits after surgery; however, these examinations did not confirm a motor deficit less than Grade 5. Subset analysis showed that the L3–4 and L4–5 levels were most often affected.

**Conclusions.** The minimally invasive, transpsoas muscle approach to the lumbar spine has a number of advantages. The data show that a percentage of the patients undergoing the transpsoas approach will have temporary sensory and motor symptoms related to this approach. The majority of the symptoms are thought to be related to psoas muscle inflammation and/or stretch injury to the genitofemoral nerve due to the surgical corridor traversed during the operation. No major injuries to the lumbar plexus were encountered. It is important to educate patients prior to surgery of the possibility of these largely transient symptoms. (DOI: 10.3171/2011.7.FOCUS11137)
Our surgical technique varies slightly from the original description of the lateral retroperitoneal approach. Briefly, following general endotracheal anesthesia, patients are positioned in the lateral decubitus position, with the left or right side upward depending on local anatomy (degenerative lumbar curves, coronal imbalance, and so on). The upper leg is flexed at the hip to allow for psoas relaxation, and the patient is secured in place with all pressure points adequately padded. The bed is adjusted to obtain true anteroposterior and lateral images, while the C-arm radiography unit is maintained at perfect right angles (locked at 0° and 90°). In patients treated in the most recent 2 years, the O-arm was used with navigation during the procedure, thus minimizing radiation exposure to the surgeon and operating room staff. We use a single 3–4-cm incision with the DLIF (Medtronic) technique. With the use of finger dissection, serial tubular dilators are placed through the psoas muscle, and a single anchoring screw for the dual-bladed retractor. Once in position, cages with beveled edges, filled with Infuse (recombinant human bone morphogenetic protein [rhBMP-2] [Medtronic], are directed into place under fluoroscopy or monitored with O-arm navigation. Of note, rhBMP-2 is FDA approved for anterior interbody fusion. However, we routinely inform and obtain consent from patients for the off-label use in the LLIF procedure.

Specific approach-related questionnaires were given in the immediate (0–8 weeks) and long-term follow-up periods. If patients reported yes to any of the questions they were monitored for longer time periods. The following questions were asked: 1) On the side you had surgery, did you have new weakness in that leg following surgery? (Particularly, when flexing the hip or lifting your entire leg?) 2) On the side you had surgery, did you have new pain in leg following surgery? (Specifically, in the front of your thigh/groin?) 3) On the side you had surgery, did you have new numbness in leg following surgery? (Specifically, in the front of your thigh/groin?)

Each question specified whether the symptoms were persistent or resolved. Also, the duration and severity of symptoms were quantified. An additional question asked if an abdominal wall hernia developed at the site of surgery. Complete follow-up, including questionnaires and physical examinations in the clinic setting, was obtained in 53 patients (102 levels). Of the 102 total levels, 22 were single-level cases treated with DLIF, and 31 were multilevel cases.

The primary objectives were to evaluate 1) transpsoas muscle edema causing hip flexor weakness; 2) GFN irritation causing numbness and/or pain; and 3) lumbar plexus/nerve root injury.

**Results**

Thirty-six percent (19 of 53) of patients experienced some transpsoas approach–related symptoms including subjective hip flexor weakness, and 84% reported complete resolution by 6 months, most of which were resolved by 2 months. Only 1 patient reported symptoms after 2 years, although clinical testing did not confirm the patient’s complaints. Twenty-five percent (13 of 53) reported new thigh/groin numbness on the side of surgery; 69% of these patients reported returning to normal by 6 months after surgery, the majority of whom reported taking most of that time to recover. Twenty-three percent of patients reported new thigh/groin pain, and 75% of these patients reported resolution of their pain by 6 months. These patients experienced this pain for a shorter time than those who reported sensory loss. One patient reported very mild persistent numbness and pain in the groin 1 year after surgery. There were no nerve root/lumbar plexus injuries.

A subset analysis of the single-level operations was performed. Thirty-three percent (3 of 9) of patients undergoing procedures at L3–4 and 57% (4 of 7) of those undergoing procedures L4–5 reported hip flexor weakness. Twenty-five percent (1 of 4) of patients undergoing procedures at L2–3 reported hip flexor weakness; none of those undergoing procedures at the L1–2 and T12–L1 levels reported this weakness. Thirty-nine percent (12 of 31) of patients undergoing multilevel procedures reported hip flexor weakness. The difference between levels did not reach statistical significance using logistic regression analysis (weakness $p = 0.24$, pain $p = 0.82$, and numbness $p = 0.27$). There were no vascular injuries. One patient experienced a psoas hematoma requiring transfusion, but reoperation was not required. In 1 case, the segmental artery was lacerated, which was successfully repaired with bipolar electrocautery.

**Discussion**

The advances in minimally invasive techniques have surfaced in anterior and posterior approaches. In the mid-1990s, there were several reports of ALIFs that used a laparoscopic approach.5,24 These primarily targeted the L5–S1 and L4–5 disc spaces. Wide use and acceptance of the laparoscopic ALIF was deterred by the known challenges and complications of laparoscopic spine surgery. Reports of retrograde ejaculation,4,7 vascular injury,2 anesthetic complications,9 need for an access surgeon, and steep learning curve all limited the popularity of this procedure.13

The retroperitoneal approach to the lumbar spine was first reported by Harmon10 in 1963. This surgical trajectory takes advantage of a natural corridor in the retroperitoneal space that leads to the lateral aspect of the spine. Mayer and Wiechert14 described a “minimally invasive retroperitoneal approach” where the length of incision could be drastically shortened as the surgeon gains more experience. Saraph et al.2 compared the traditional open approach described by Harmon with the minimally invasive approach of Mayer and Wiechert and showed less blood loss and shorter hospital stays and described shorter incisions. The minimally invasive length of incision ranged from 6 to 20 cm versus the traditional approximately 50-cm-long incisions that a general surgeon would
use to access the spine. These authors reported no statistical difference with respect to standard complications. They reported that 5 (9%) of 56 patients suffered injury to the lateral femoral cutaneous nerve. It is important to note that in this approach, the psoas muscle is retracted posteriorly.

The endoscopic retroperitoneal approach to the spine had also been used in the past. Bergey et al.3 reported a series of 21 patients who underwent an endoscopic, lateral retroperitoneal, transpsoas approach to the anterior spine for interbody fusion. This was the first report of a transpsoas approach to the spine. These authors discussed the anatomical considerations of the approach, as well as their experience with approach-related morbidity. They reported an average surgical time of 149 minutes and a mean hospital stay of 4.1 days.3 They used the following 4 ports: a working port (1 cm), a suction port (0.5 cm), a laparoscopic port (1 cm), and a psoas retractor port (1 cm). The total incision was approximately 3.5–4 cm. The authors used BAK cages in the interbody space with autograft. They reported that 6 patients (30%) developed transient postoperative groin/thigh paresthesias. Also, 5 (27%) of these patients complained of groin/thigh pain. The authors did not mention whether any of the patients had postoperative hip flexion weakness. Groin/thigh pain in 2 patients persisted beyond 1 month. In 1 of these patients, there was persistent pain in his anterior thigh 11 months after surgery, which was treated with Neurontin. The authors concluded that their approach is safe, with some patients experiencing symptoms related to the transpsoas corridor.

Özgur et al.18 described, in a step-wise manner, the eXtreme Lateral Interbody Fusion (XLIF) (NuVasive, Inc.), which is a minimally invasive, lateral retroperitoneal, transpsoas approach to the anterior spine for interbody fusion. A 2-incision technique was described for the approach, with an anchorless 3-blade retractor, and early clinical results were discussed.18 The first incision was 3–4 cm, with a second more posterior incision of about 2 cm.18 In the 13 patient series, all were supplemented with posterior percutaneous pedicle fixation, and the authors reported an average 45 minutes per level surgical time. The authors reported no complications in their first 13 patients.

Recently, Knight et al.12 reported a series of 58 patients who underwent a DLIF or XLIF minimally invasive, lateral retroperitoneal, transpsoas approach to the spine. The authors focused on mild or major adverse events during hospital stay or within 6 weeks of discharge and reviewed the charts. They reported that adverse events occurred in 18 of 58 patients, and 13 of 58 had major or mild complications. Nine complications were approach-related: there were 2 cases of ipsilateral L-4 nerve root injury, 6 cases of irritation of lateral femoral cutaneous nerve resulting in meralgia paresthetica, and 1 case of significant psoas muscle spasm leading to an extended hospital stay. The authors did not mention any significant transpsoas weakness in their complication profile. They concluded that DLIF techniques have proven to be of value in management of lumbar degenerative conditions.12

There are several published papers and abstracts that describe morbidity of the minimally invasive lateral lumbar interbody fusion, but most do not specifically focus on transpsoas muscle morbidity.11,12 In our experience, there are 3 primary symptoms associated with the transpsoas approach, including thigh and/or groin pain and numbness, as well as hip flexion weakness. These symptoms are most often temporary and resolve within 2 months. Initial findings were elicited on postoperative motor and sensory examinations while patients were still in the hospital, and they were not due to patients explicitly complaining of weakness, numbness, or pain in the thigh/groin area. It is important to mention that only a few of these patients volunteered the information in the postoperative setting. This might indicate that the signs and symptoms were mild and not affecting the patient’s overall functional status or well being. The patients who reported weakness on the questionnaire were examined and found to have full motor function on physical examination.

Hip flexion weakness is likely due to splitting the psoas muscle. It is theorized that the muscle undergoes a postoperative edematous reaction, which contributes to the dysfunction. The more cephalad disc spaces do not have as much psoas muscle over the lateral body wall, so at L2–3 and above, transpsoas muscle weakness is rarely an issue. Thirty-six percent of the patients reported these symptoms; 50% of them had resolution of their weakness by 2 months, and 84% were normal by 6 months. One patient reported persistent symptoms at 2 years; however, this was not reflected in gait and could not be detected on physical examination.

The thigh/groin pain and numbness are likely due to manipulation of the GFN. The GFN arises from L1–2 roots and passes obliquely through the substance of the psoas. It emerges at the L3–4 level on the anterior surface of the psoas muscle and travels inferiorly covered by the peritoneum to divide into the genital and femoral branches. Symptoms most frequently include medial thigh and groin pain and/or numbness; 23% and 25% of patients, respectively, reported these symptoms. There are no reliable electrodiagnostic tests that can be used for diagnosis of injury to this nerve. Upon the initial surgical approach, careful inspection of the muscle at these levels may avoid excessive manipulation of the GFN. As one would expect, our study showed that these symptoms took longer to recover than the symptoms of hip flexor weakness, with pain resolution first followed by the sensory deficit. Fifty percent of those experiencing thigh and/or groin pain had resolution by 2 months, and a total of 75% resolved by 6 months. In contrast, 15% of patients reporting numbness had resolution by 2 months, and 69% had resolution by 6 months. Patients who reported dysesthetic pain were treated with Neurontin or pregabalin; this medical therapy conferred pain relief to varying degrees. The medications were gradually tapered as the symptoms resolved. One patient reported that numbness and pain that lasted longer than 1 year, although the symptoms at 1 year were mild and did not require medication.

We encountered no lumbar plexus or nerve root injuries. Since the upper lumbar plexus innervates the iliopsoas muscle, one could contest that an injury to the upper lumbar plexus could not be distinguished from the transpsoas weakness due to muscle swelling. Also, injury
to the upper plexus (L1–2 nerve roots) could cause some of the symptoms associated with GFN irritation. We acknowledge this to be a possibility; however, we would expect other neurological findings referable to the L-1 or L-2 nerve roots. A recent report evaluated other peripheral nervous structures at risk during the lateral approach to the lumbar spine.\textsuperscript{14} This cadaveric study nicely characterized the main motor and sensory branches of the lumbar plexus outside the psoas muscle. They identified 4 other nerves at risk: the subcostal, iliohypogastric, ilioinguinal, and lateral femoral cutaneous nerves. In addition to the commonly encountered GFN, the authors appropriately concluded that the surgeon should be aware of other potential nerve palsies in the postoperative period. In our series, there was no reason to suspect injury to these other peripheral nervous structures.

The advantages of LLIF over ALIF (mini-open or laparoscopic) include avoidance of the hypogastric plexus, thus avoiding risk of retrograde ejaculation.\textsuperscript{4,21} Furthermore, the great vessels are much less a threat to the surgeon than in the anterior approach, as evidenced by incidence of injury.\textsuperscript{2,22} In our experience and that reported by Knight et al.,\textsuperscript{12} there were no major vascular complications in a combined total of 113 patients. These advantages are recognized when working at the L4–5 level. The anterior approach can be used to visualize the L5–S1 interbody space, but the direct lateral approach cannot be used at this level given the presence of the iliac crest. Some patients may have an anatomically unfavorable pelvis and the L4–5 may not be accessible via LLIF approach as well. Endoscopic transiliac access to the L5–S1 disc has been performed in cadavers;\textsuperscript{17} however, to our knowledge this has not been attempted in patients. Also, the lumbar plexus is anatomically most anterior along the vertebral body wall at this level,\textsuperscript{14} posing a theoretically larger risk for nerve root injury.

Conclusions

The minimally invasive, lateral retroperitoneal, transpsoas approach to the anterior spine is a viable and safe option for accessing the interbody space. The morbidity of the transpsoas approach can be divided into the following 3 categories: 1) transpsoas swelling causing hip flexor weakness, 2) GFN irritation causing numbness and/or pain of the thigh/groin area, and 3) lumbar plexus/nerve root injury. Patients did not typically complain of these symptoms; rather, they were discovered during the investigation, which is possibly an indication of their severity. Preoperatively, patients undergoing this specific approach should be warned of the possibility of hip flexor weakness due to psoas swelling and the possibility of a transient thigh/groin numbness and pain due to GFN irritation in addition to the standard preoperative discussion. Patients can be reassured that most of these symptoms will resolve with time if they do experience them.

Complication avoidance is of paramount import, and there are several key steps that minimize morbidity. As mentioned in Methods, once the final tube is secured in position, we directly visualize the psoas muscle. This ensures that there are no nerves crossing the surgical corridor, especially the commonly encountered GFN. Perhaps the greatest impact on postoperative psoas-related morbidity involves the extent of psoas muscle dilation. Over the years, one of the senior authors (J.C.L.) has modified the technique such that the psoas muscle is no longer traversed with the dilators. Instead, the tubes are docked to rest on the psoas. Using a Penfield No. 4 dissector, the psoas is carefully and bluntly dissected in an atraumatic fashion. Theoretically, this maneuver might lead to less muscle tissue trauma and therefore result in less postoperative psoas-related morbidity. The clinical results of this variant in surgical technique are currently under review with anticipated future publication.

Disclosure

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