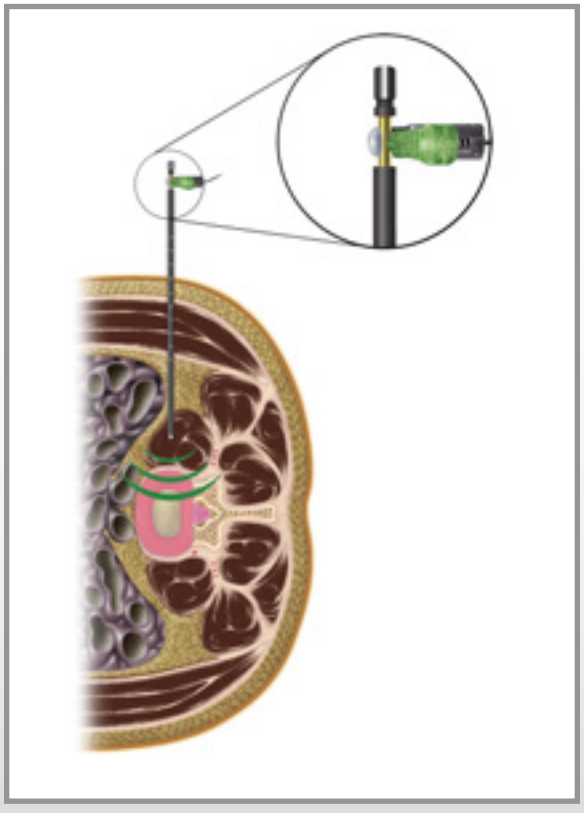
Part I

Fundamentals



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History of the Lateral Approach

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It is with great enthusiasm that we witness the publication of this second edition of *eXtreme Lateral Interbody Fusion (XLIF®)*. In the years since the earliest descriptions of the technique, the XLIF (NuVasive®, Inc., San Diego, CA) approach has become widely used in the treatment of multiple pathologies of the adult thoracolumbar spine. As a less invasive alternative to anterior column access, the lateral approach largely avoids the vascular, visceral, and sympathetic risks associated with traditional direct anterior approaches and the morbidity associated with the bony, muscular, and ligamentous dissection of traditional posterior approaches. The approach has been used in a growing number of applications, from treatment of single-level degenerative conditions to multilevel complex deformity corrections, treatment of traumatic fractures, treatment of infections, tumor removal, revisions of previous surgeries, and total disc replacement. The published reports of XLIF for these applications have grown concomitantly and provide evidence to support the advantages of the minimally invasive approach and the longer-term efficacy of the constructs achieved.

Indeed, the positive results of the XLIF procedure have themselves been the impetus for the growth of its use. Since the publication of the first edition of *eXtreme Lateral Interbody Fusion (XLIF®)* in 2008, several device manufacturers have developed devices to mimic the procedure as first described using NuVasive's platform of access (MaXcess®, NuVasive, Inc.), integrated neural monitoring (NVJJB®/M5®, NuVasive, Inc.), and pathology-specific implants (CoRoent®, NuVasive, Inc.).[1] It is therefore worthwhile to review the rationale for the lateral approach and the methods used in historical approaches as well as the evolution of the XLIF procedure to what it is today.

Spinal fusion was first reported in the literature in 1911, independently by both Hibbs[2] and Albee,[3] as a treatment for deformity resulting from tuberculosis (Pott's disease). Historically, fusion was most commonly performed along the posterior aspect of the spine, using autograft from decompressive dissection, and in time using internal fixation options such as rods with hooks, wiring, and ultimately pedicle-based fixation.[4-7]

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The 1930s heralded early reports of fusion of the anterior column (i.e., interbody fusion) for the treatment of lumbosacral spondylolisthesis by direct transperitoneal anterior approach,[8] what became commonly known as anterior lumbar interbody fusion (ALIF). Anterior column (interbody) fusion has the advantages of greater surface area, greater vascularity, and greater load than the posterior column, all of which are important to the biologic process of fusion.

Lumbar interbody fusion from a posterior approach, or posterior lumbar interbody fusion (PLIF), was first described in the 1940s, when Jaslow[9] and Cloward[10] separately reported the use of bone plugs to replace the discectomy defect in the treatment of degenerative disc herniation. A posterior approach to anterior column access has the advantage that a direct neural decompression can be performed, if necessary, during the same procedure. In cases where aggressive decompression is not necessary, however, the morbidity of the muscle retraction and bony and ligamentous resection necessary to gain access to the disc space is a distinct disadvantage. Furthermore, a direct posterior approach to the anterior column requires retraction of the cauda equina and risks injury to the lumbar nerve roots. A modified, unilateral approach, transforaminal lumbar interbody fusion (TLIF), was first reported by Harms in 1982, wherein bony dissection was limited to one side, thereby theoretically requiring less dural retraction.[11] Fig. 1-1 shows the various approach options to the anterior column of the lumbar spine.

The original abdominal approach to anterior column access obviates some of the approach-related disadvantages of posterior approaches, but it is not without its own challenges. The morbidity of the anterior approach includes abdominal muscle dissection, mobilization of the abdominal contents (either transperitoneal or retroperitoneal), and mobilization of the major vasculature anteriorly adjacent to the spine. This generally requires the collaboration of an access surgeon alongside the spine surgeon.

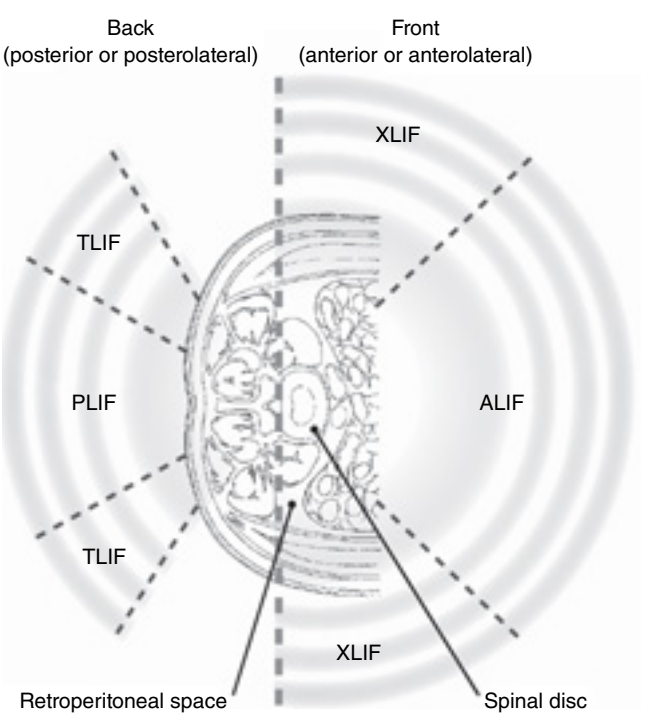

FIG. 1-1 A lumbar cross-section and the delineation of anterior (i.e., abdominal) and posterior (i.e., through the posterior musculature) procedures.

Although early ALIF techniques required large exposures and produced significant morbidity, the direct anterior approach has evolved over time and has included the use of laparoscopic techniques and now commonly what is considered a mini-open technique.

ANTERIOR LUMBAR INTERBODY FUSION

The anterolateral retroperitoneal approach to the anterior column of the spine has a long history of clinical success since its first reported use for Pott's disease and spondylolisthesis. Today it is used for a variety of indications, including degenerative disc disease, spondylolisthesis, and posterior pseudarthrosis, among other conditions. Anterior column access and stabilization is very well documented; today there are more than one thousand published articles on anterior, lateral, and anterolateral lumbar interbody fusion. Average outcomes, despite minor differences in surgical technique, are reportedly high.

The original technique described a midline transperitoneal abdominal approach with the patient in a supine position. Conventional large open anterior approaches fell out of favor because of vessel injuries, presacral plexus injuries, urinary retention, retrograde ejaculation, and abdominal muscle weakness caused by the large incision and extensive anatomic dissection. Subsequent efforts have been made to make the anterior approach safer, less invasive, and more reliable. Modifications over time have included paramedian incisions and retroperitoneal access to prevent the complications of direct anterior mobilization and manipulation of the contents of the peritoneum.

Fraser reported the use of a wide, muscle-splitting extraperitoneal approach to the lumbar spine.[12] The development of endoscopic and laparoscopic techniques repopularized anterior surgery in the late 1990s and early 2000s.[13-15] However, these techniques gave way to mini-open approaches to anterior lumbar spinal surgery because the latter was found to be easier to learn, is less expensive, and offers direct visualization and a more hands-on approach.[15-17] The ALIF technique now largely employed is a mini-open retroperitoneal approach, using blunt dissection of the abdominal musculature, manual/digital dissection/expansion of the retroperitoneal space, and the use of self-retaining retractors (of various designs) for maintained exposure, with direct visualization of the anterolateral aspect of the spine.

Regardless of the terminology used, the steps and the end objective are the same: access to the anterior column of the thoracolumbar spine from within the retroperitoneal space, removal of the intervertebral disc and preparation of the vertebral endplates, and insertion of a spacing interbody implant, with biologic grafting materials and internal fixation as necessary for the ultimate goal of realignment of the spine, decompression of neural structures, and interbody fusion.

A more lateral retroperitoneal approach to interbody fusion, however, could accomplish the same objectives with significantly reduced exposure time, muscle dissection, and associated postoperative morbidity. It would prevent ligamentous destabilization and the need for vascular mobilization, while still affording superior exposure of the disc for optimal disc space preparation and implantation of a large implant that could span the disc space laterally for greatest stability and anatomic correction. Access to the lateral aspect of the disc space, however, was historically limited by the psoas muscle and the nerves of the lumbar plexus that run through it.

LATERAL (ANTEROLATERAL) INTERBODY FUSION

Early reports of a lateral approach to the spine described an anterolateral retroperitoneal trajectory, placing interbody implants obliquely, with dissection and retraction of the psoas posteriorly.[18-20] Others placed the interbody implants directly lateral to improve the biomechanical advantage and obviate the more anterior disc exposure—still, however, dissecting and retracting the psoas muscle posteriorly for exposure.[21-23] Retracting the psoas muscle posteriorly may contribute to the incidence of new postoperative neural deficit and/or muscle weakness from muscle swelling and/or compression of the nerves of the lumbar plexus that reside within the psoas muscle posteriorly.[24] Approaching the spine by *traversing* the psoas muscle minimizes retraction pressure on the nerves, but also poses a risk of direct nerve

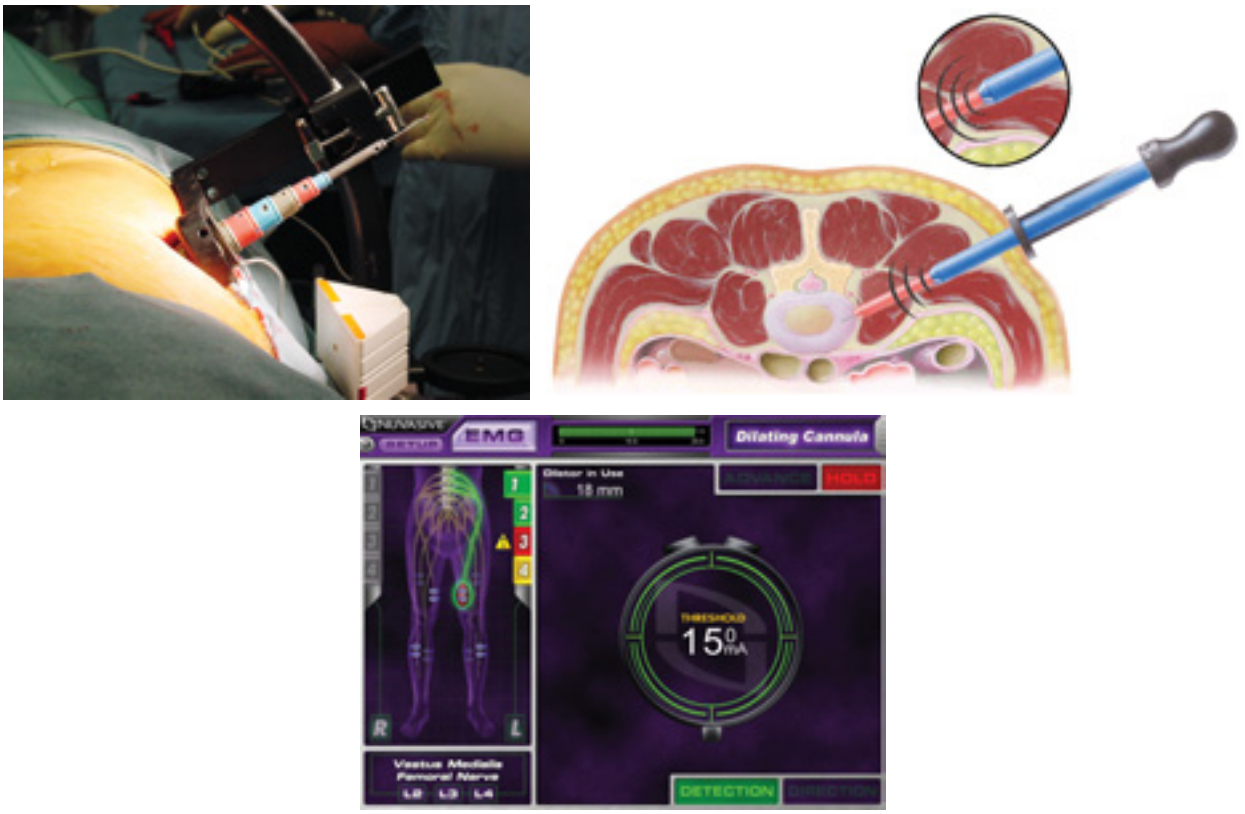

FIG. 1-2 Early attempt at transpsoas approach in a prone position, what is sometimes referred to as XLIF®-60 (NuVasive, Inc.) to differentiate it from the 90-degree approach commonly used today and called XLIF. The approach used evoked EMG guidance through the psoas muscle, but it required tubular exposure and was anatomically limiting due to the navigation of the lumbar plexus required in this trajectory. (From Malberg M. eXtreme lateral interbody fusion [XLIF]. In Regan J, Lieberman I, eds. Atlas of Minimal Access Surgery, 2nd ed. St Louis: Quality Medical Publishing, 2004.)

injury during disc exposure. To overcome that concern, Bergey et al[25] used optical trocars and/or endoscopes for videoscopic visualization of the tissues during exposure. The results with this method in 21 patients, however, included a 30% incidence of transient postoperative groin/thigh paresthesias.

Early attempts to include evoked EMG monitoring to traverse the psoas muscle were described but employed a posterolateral 60-degree approach, with the patient prone[26] (Fig. 1-2). Procedures performed in this orientation frequently met with challenging approach logistics, as the nerves of the lumbar plexus frequently were identified as in the path and difficult to navigate around for safe access to the disc. Placement of interbody spacers was from a less ideal trajectory as well. Although use of this technique led to advancements and validation of the EMG monitoring,[27] concerns for the safety of the approach limited its applicability and use.

Introduction to XLIF

We first presented in Brazil on what was then called the *lateral endoscopic transpsoas retroperitoneal approac*h (LETRA) procedure in 2001.[28] The LETRA technique employed the use of blunt finger dissection of the retroperitoneal space, but with tubular portals with endoscopic visualization and without EMG monitoring (Fig. 1-3). A report of the first 85 patients to undergo this procedure included a 14% incidence of postoperative psoas weakness and 3.5% incidence of slight thigh atrophy.[29]

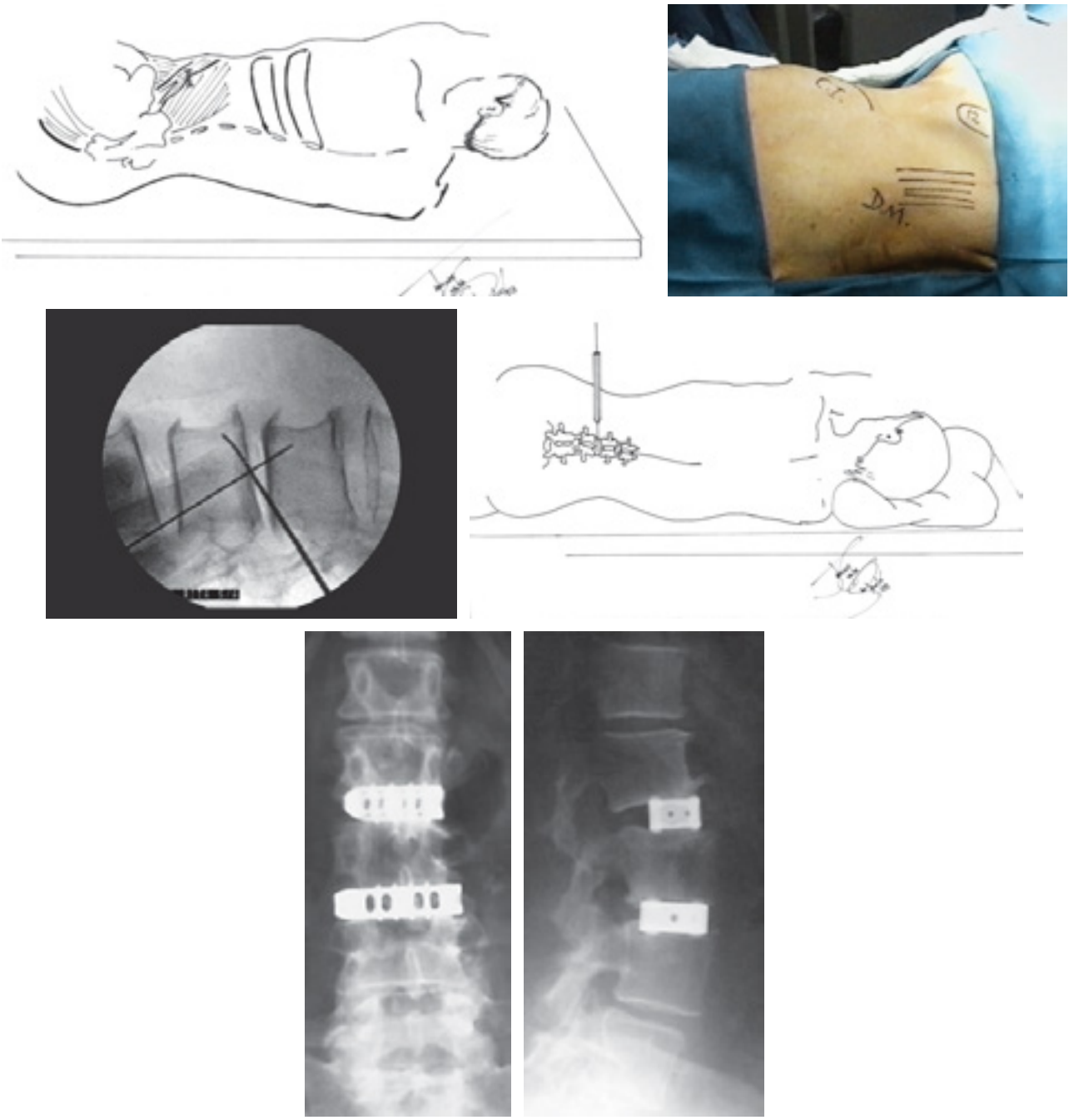

FIG. 1-3 Early Brazilian experience with LETRA, before collaboration for the XLIF® (NuVasive, Inc.) product design. (From Pimenta L, Figueredo F, DaSilva M, McAfee P. The lateral endoscopic transpsoatic retroperitoneal approach [LETRA]: a new technique for accessing the lumbar spine. Presented at AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves, San Diego, 2004.)

Since that time, the MaXcess retractor system for minimally disruptive spine surgery was developed to overcome the disadvantages of working through tubular portals, which in the lateral approach may also inadvertently put pressure on nerves within the psoas by radially expanding the exposure. Through the customizable exposure of the MaXcess retractor, direct visualization is possible and improves the visibility of anatomic structures over what can be seen endoscopically (Fig. 1-4). In addition to the MaXcess retractor, the use of NVJJB®/M5® EMG nerve monitoring has replaced blind psoas traverse or sole reliance on directly visualizing neural structures to protect their integrity.

Several authors have since reported improved short- and long-term outcomes using this complement of tools, under what is now known as the XLIF technique. Although there are an increasing number of procedural variants being presented today, the XLIF technique, by definition, is a 90-degree lateral, retroperitoneal approach to access the anterior column with minimal muscular disruption or trauma to nearby structures by use of blunt finger dissection of the retroperitoneal space, tactile guidance of an initial dilator to the surface of the psoas muscle, evoked dynamic discrete-threshold EMG guidance of the dilator through the psoas, expansion of a split-blade retractor system that provides a customizable working channel and direct visualization, and placement of a large interbody implant that spans the ring apophysis for maximized correction and greatest biomechanical advantage.

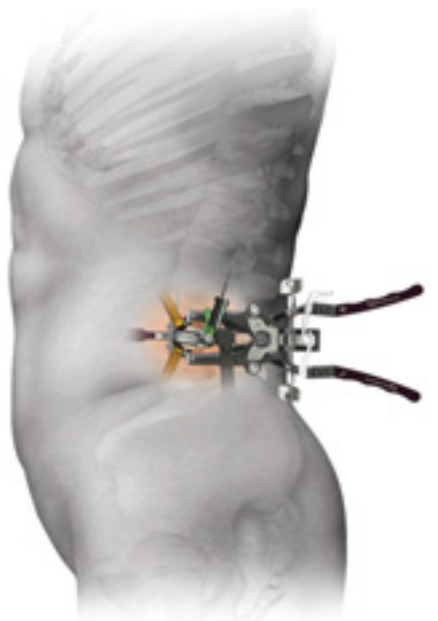

FIG. 1-4 The modern XLIF® (NuVasive, Inc.) uses direct illuminated visualization through the MaXcess® (NuVasive, Inc.) retractor.

GROWTH OF A PROCEDURE

In 2008 the first edition of this textbook on the XLIF approach was published; it covered standard surgical techniques and various clinical applications.[30] There were few peer-reviewed published reports of clinical outcomes, but there was significant anecdotal enthusiasm for the approach. Early use of the lateral approach was for relatively noncomplex procedures: one- or two-level interbody fusion for lumbar degenerative conditions. Today applications of the lateral approach have expanded to include conditions spanning the thoracic and lumbar regions, degenerative back *and* leg pain, deformity, trauma, tumor, infection, revision, motion preservation, and so on—in short, any indication requiring access to the anterior column of the thoracolumbar spine.

The tools at our disposal have evolved along with the indications. The CoRoent XL line of polyetheretherketone (PEEK) spacers includes options for various patient demands such as width, length, sagittal angle, coronal angle, integrated fixation, and so on. Supplemental fixation options have expanded over the years as well, with single-approach options such as lateral plating and single-position posterior options such as unilateral pedicle screws, facet screws, and spinous process fixation. Access has incrementally improved as well, as we have learned more through the years; the MaXcess retractor is now in its fourth generation.

Today the published literature provides even greater insight into the applications and outcomes of the XLIF procedure. As of this writing, there are more than 100 peer-reviewed articles on XLIF, and hundreds of abstracts and posters have been presented at scientific meetings. These results will be recounted in the following chapters, and so are not enumerated here. The scope

of the work done, however, deserves mention. Much of the research and publication efforts have been born from the Society of Lateral Access Surgery (SOLAS®), founded in 2006 as a venue for collaborative research and education around the XLIF procedure. It has provided its growing membership with support of single-center and multicenter research as well as a platform for the discussion of clinical best practices to maximize patient outcomes.

THE FUTURE OF LATERAL ACCESS SURGERY

We anticipate that through continued evolution and increased specification, we can continue to improve individualized patient care. The research effort has been further advanced by community-wide registry data collection for continued validation of new applications. Opportunity abounds for the development and/or refinement of additional minimally invasive procedures based on what we have learned from the lateral approach experience.

The XLIF procedure has revolutionized how interbody fusions can be performed, more safely and with significantly less morbidity. As other devices purported to be designed for lateral approach surgery become available, it is important to rely on the experience that has carried this evolution, and the design features and technique details that consistently result in superior safety and clinical outcomes. The remainder of this second edition of *eXtreme Lateral Interbody Fusion (XLIF)* details that experience.

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