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### **Minimally Invasive Spine Surgery: A Historical Perspective**

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Minimally invasive spine surgery has gained considerable momentum and increased acceptance among spine surgeons throughout the years. An understanding and awareness of the development of minimally invasive spine surgery and its role in the operative treatment of various spine conditions is imperative. This article provides a succinct historical perspective of the development of spine surgery from the more traditional, open procedures to the use of more "minimal access" or minimally invasive spine surgery procedures.

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The percutaneous endoscopic discectomy (PECD) with working channel endoscope (WSH) endoscopy set could be a safe and effective minimally invasive surgical option for non-contained cervical disc herniation in selected patients. Judicious use of the end-firing Ho: Yttrium-Aluminium-Garnet (YAG) laser for both decompressive and thermoannuloplasty effect during the percutaneous endoscopic cervical annuloplasty (PECA) is mandatory in order to prevent possible injury to spinal cord or root. Although the percutaneous cervical stabilization (PCS) using the cervical B-Twin may not completely replace the cervical arthrodesis, this minimally invasive procedure can preserve anterior structures and thereby retain segmental stability and prevent the possible kyphotic progression after fusion surgery. To our knowledge, these minimally invasive procedures for cervical spine disease may serve to minimize surgery-induced complications associated with anterior cervical discectomy and fusion (ACDF).

### **Posterior Minimally Invasive Approaches for the Cervical Spine**

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Cervical microendoscopic foraminotomy/discectomy and cervical microendoscopic decompression of stenosis are highly effective, minimally invasive approaches to cervical radiculopathy due to foraminal osteophytes or lateral disc herniation and cervical spondylotic myelopathy, respectively. The operative technique utilized in each of these procedures is described in detail, together with the advantages of the minimally invasive technique over traditional open approaches. Complication avoidance and management is also discussed.

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Hormoz Sheikh, Dino Samartzis, and Mick J. Perez-Cruet	

Thoracic disc herniations are uncommon lesions that are asymptomatic in most patients; however, for individuals who present with persistent radiculopathy that is nonresponsive to conservative treatment or with myelopathic symptoms with or without radiculopathy attributed to a thoracic disc herniation, operative intervention of the thoracic spine is sought. Various procedures and approaches for the treatment of thoracic disc herniations have been reported, but they have been associated with numerous intraoperative complications and postoperative morbidities. This article discusses a novel minimally invasive procedure for the surgical treatment of thoracic disc herniations referred to as a minimally invasive thoracic microdiscectomy. It uses a series of muscle dilators, a tubular retractor, and microscopic visualization by way of a posterolateral approach in an effort to minimize many of the complications that are associated with the more traditional approaches.

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Traditionally, minimally invasive techniques for surgical discectomy have been defined as smaller incisions, tubular retractors, microscopically assisted tissue dissection, and conservative removal of only extruded or sequestered nucleus pulposus with preservation of the annulus. The first truly minimally invasive technique was chymopapain dissolution of the nucleus pulposus. Other percutaneous techniques followed; however, none were as efficacious as the gold standard of microlumbar discectomy until endoscopically visualized methods evolved to allow visualized mechanical discectomy through the foramen. In experienced hands, such a technique is as effective as microlumbar discectomy and results in less surgical morbidity for herniations that are appropriate for this minimally invasive endoscopic surgical portal that completely avoids traumatizing the normal anatomy of the dorsal musculature and ligamentous structures.

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Lumbar spinal fusions have been performed for nearly a century for a variety of spinal conditions and include posterior/posterolateral and anterior lumbar interbody fusions. Traditionally, the ability to achieve adequate exposure to perform these procedures required an open surgical approach; however, the advent of newer techniques and technology, combined with an improved understanding of surgical anatomy, has resulted in newer minimally invasive techniques. Posterior approaches include posterior and transforaminal lumbar interbody fusions, whereas anterior techniques include retroperitoneal and transperitoneal anterior lumbar interbody fusion approaches. More recently, the extreme lateral interbody fusion and axial lumbar interbody fusion have been described. This article provides a general review of the history, indications, brief overview, and description of the more common minimally invasive spine surgery techniques used for achieving a lumbar interbody fusion.

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Standard open posterior decompression is well established and familiar to virtually all spine surgeons. However, this traditional surgical treatment of lumbar spinal stenosis

(LSS) is often associated with significant postoperative pain, disability, and dysfunction. This article reviews the use of a minimally invasive microendoscopic approach for bilateral decompression of lumbar stenosis by way of a unilateral approach. This technique has been shown to provide symptomatic relief equivalent to that of open discectomy, with significant reductions in operative blood loss, postoperative pain, hospital stay, and narcotic usage. Furthermore, the article explains the rationale, indications, and surgical techniques for minimally-invasive LSS surgery and presents the authors' 4-year outcomes data.

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D. Greg Anderson, Dino Samartzis, Francis Shen, and Chadi Tannoury

The development of percutaneous instrumentation systems has been a significant milestone in the ability of surgeons to perform complex spinal procedures through minimally invasive approaches. These systems rely on cannulated screws or portal systems and using intraoperative imaging to allow accurate placement of the spinal implants without a full traditional exposure of the spine. This article reviews the operative concepts and techniques used to place percutaneous instrumentation in the thoracolumbar spine.

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Dhruv B. Pateder, A. Jay Khanna, and Isador H. Lieberman

Osteoporotic vertebral compression fractures have previously been treated nonoperatively given the tremendous morbidity associated with open fixation in elderly patients who often have multiple medical comorbidities. With the advent of percutaneous vertebral augmentation techniques, these fractures can now be stabilized using minimally invasive surgical techniques while maintaining a relatively safe risk profile. Vertebroplasty and kyphoplasty provide immediate pain relief in the great majority of patients who have painful, osteoporotic vertebral compression fractures. The balloon used in kyphoplasty may allow for improved height restoration, cavity creation, and decreased cement extravasation rates. The authors discuss the procedural steps, advantages and disadvantages, and results of each technique, recognizing that prospective, randomized controlled studies are necessary to objectively compare the two techniques.

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The thoracolumbar junction is the most common region of the spine to be affected by injuries. Acute instability with structural damage to the anterior load-bearing spinal column and posttraumatic deformity represent the most frequent indications for surgery. A standardized operating technique with instruments and implants specially developed for the endoscopic procedure, ranging from an angled, stable plate and screw implant to endoscopically implantable vertebral body replacements, have gradually opened up the entire spectrum of anterior spine surgery to endoscopic techniques at the thoracolumbar junction.

### **Emerging Minimally Invasive Technologies for the Management of Scoliosis**

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Baron S. Lonner

Surgery for scoliosis has evolved dramatically over the past century—from posterior surgery and casting that resulted in poor deformity correction and high pseudarthrosis rates and that required prolonged bed rest to anterior thoracoscopic and miniopen approaches that result in reproducible curve correction ranging from 55% to 70% with high fusion

rates. The future of scoliosis surgery lies in the application of growth-modulation approaches by way of minimally invasive techniques, which will result in curve correction while maintaining spinal motion and disc and motion segment integrity. The optimal approach will use genetic testing to predict curve progression, thereby providing the clinical data required for determining the appropriate candidate for the use of this strategy.

**The Role of Minimally Invasive Techniques in the Management of Spine Tumors: Percutaneous Bone Cement Augmentation, Radiosurgery, and Microendoscopic Approaches**

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Peter C. Gerszten

In a similar manner to which patients with degenerative spinal disorders have benefited from advances in minimally invasive spine surgery techniques, patients with spine tumors may benefit from the option of less invasive techniques for tumor ablation, resection, reconstruction, and stabilization. Percutaneous bone cement augmentation, radiosurgery, and microendoscopic approaches for the treatment of spine tumors have allowed for improved clinical outcomes while limiting procedure-related morbidity in this unique patient population.

**Image Guidance in Spine Surgery**

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Langston T. Holly and Kevin T. Foley

Computer image guidance is one of the most significant recent technologic advancements in the field of spine surgery, because preoperative or intraoperative images can be used for multiplanar, three-dimensional intraoperative navigation. Laboratory and clinical studies have demonstrated that image guidance increases the safety and accuracy of a variety of spinal procedures. This article describes the application of intraoperative image guidance to spinal surgery, with a particular focus on minimal access procedures. Although commonly performed separately, these techniques can work in a complementary fashion. The apparent benefits and limitations of the various image-guided modalities are described.

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