A brief history of endoscopic spine surgery

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Few neurosurgeons practicing today have had training in the field of endoscopic spine surgery during residency or fellowship. Nevertheless, over the past 40 years individual spine surgeons from around the world have worked to create a subfield of minimally invasive spine surgery that takes the point of visualization away from the surgeon's eye or the lens of a microscope and puts it directly at the point of spine pathology. What follows is an attempt to describe the story of how endoscopic spine surgery developed and to credit some of those who have been the biggest contributors to its development.

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THE history of endoscopic spine surgery has involved 3 phases: inspiration, invention, and innovation.

The inspired early practitioners sought a means of accessing lumbar disc herniations that would be less invasive than traditional open techniques. The early endoscopic surgeons targeted disc pathology through a corridor that would become known eponymously for its originator, Dr. Parvis Kambin. Invention would then be required to make endoscopic discectomy a feasible and then a successful procedure: better working-channel rigid endoscopes, high-definition cameras, drills, trephines, articulated graspers, and other instruments (Fig. 1). With 50 years of groundwork on which to build, the innovators now have the tools and background knowledge to treat a myriad of spine pathologies beyond the herniated lumbar disc for which the technique was intended. The story of endoscopic spine surgery is far from complete, but it demonstrates the interplay of imagination and technology in developing new surgical techniques.

Percutaneous Endoscopic Discectomy

The current position of the field of endoscopic spine surgery is the result of two directions of evolution: big-to-small and small-to-big. As in other surgical fields, the progression of surgical techniques from open to more and more minimally invasive procedures has required visualization

and instruments that would be endoscope based. However, the foundation for transforaminal endoscopic spine surgery was really the result of the evolution of a needle-based technique: percutaneous endoscopic discectomy.

A technique for percutaneous nonvisualized indirect spinal canal decompression—percutaneous nucleotomy—through a posterolateral approach was described by Parvis Kambin (Fig. 2) in 1973²⁶ and Hijikata et al. in 1975.¹² Kambin described using a Craig cannula (Fig. 1) and Hijikata a 2.6-mm cannula. The technical challenge of achieving sufficient removal of nucleus pulposus material through a needle was addressed by Kambin and coworkers in 1986 and 1987 with the introduction of working cannulas possessing diameters up to 5 mm and flexible forceps.^{27,30}

The next step in the advancement of the percutaneous discectomy technique was the addition of the endoscope. The first endoscopic views of a herniated nucleus pulposus were published by Kambin et al. in 1988,²⁹ and the first reported introduction of a modified arthroscope into the intervertebral disc space was reported by Forst and Hausman in 1983.¹¹ Schreiber et al.⁴⁷ and Suezawa et al.⁵⁰ published their bilateral approach for a percutaneous nucleotomy under endoscopic control and described injecting indigo carmine into the disc space to stain the abnormal nucleus pulposus and anular fissures.

Percutaneous endoscopic discectomy certainly must re-

FIG. 1. Instruments used in and developed for endoscopic spine surgery. **A:** Craig needle set and cannula. **B:** Working-channel endoscope with channels for irrigation and suction. **C:** Crown reamers for foraminal bone removal. **D:** Endoscopic graspers and Kerrison punches. **E:** Endoscopic drill (left) and chisel (right; arrow points to exiting nerve root). **F:** Semibendable grasper reaching cranial (right) and cephalad (left) in a foraminal decompression after placement of instrumentation.

ceive a great portion of the credit for advancing endoscopic spine surgery, but it also must likely take responsibility for endoscopic spine surgery's slow rate of acceptance as a feasible technique by most orthopedic and neurosurgical spine specialists. The surgical goal of percutaneous endoscopic discectomy is to indirectly decompress the neural elements by selectively removing the nucleus pulposus from the posterior one-third of the disc space. From its origin, the technique showed promising results: Kambin and Gellman reported a 72% success rate in 136 patients with their percutaneous technique in 1983, but it has been difficult to quantify the impact of such results because they were not matched with nonoperative controls.²⁸ Thus, percutaneous endoscopic discectomy represented what is only an indirect spinal decompression, but a direct and very powerful new surgical approach to spinal pathology.

Kambin's Triangle

In 1990, Parvis Kambin described a triangular safe zone bordered by the exiting root anteriorly, the traversing root medially, and the superior endplate of the lower lumbar vertebra inferiorly.²⁶ The anatomical description of this safe zone allowed the field of endoscopic spine surgery to outgrow the technique of percutaneous nucle-

otomy, which was limited by the use of small needlelike instruments. Kambin's triangle was a working corridor that allowed larger instruments and working channels to be introduced in even closer proximity to foraminal pathology without injuring the exiting nerve.

Foraminoscopy

With the idea of a safe working triangle between the exiting and traversing roots in the foramen, endoscopic spine surgery started to leave the safety of the indigo carmine blue-stained nucleus and explore the foramen. In 1993 Mayer and Brock used an angled lens scope that allowed more dorsal visualization of annular pathology.³⁸ Foraminoscopy was described by Mathews in 1996³⁷ and Ditsworth in 1998.⁹ In 1996 Kambin and Zhou described lumbar nerve root decompression by anulectomy and decompression of lateral recess stenosis with the use of forceps and trephines.³¹ In 2005 Schubert and Hoogland (Fig. 2) described their technique for transforaminal endoscopic removal of a sequestered disc fragment using reamers to expand the foraminal window by removing the ventral portion of the superior articular process.⁴⁸ Multichannel endoscopes with larger working channels were introduced by Tsou et al. in 1997⁵⁵ and Ruetten (Fig. 2) et al. in 2007.⁴⁶

FIG. 2. Photographs of some of the inventors and innovators in the field of endoscopic spine surgery. **A–F:** Parvis Kambin, Michael Schubert, Thomas Hoogland, Sebastian Ruetten, Anthony Yeung, and Kevin Foley.

A number of reports of the clinical success of direct endoscopic decompression of foraminal pathology would follow: Yeung (Fig. 2) and Tsou in 2002,⁵⁹ Ruetten et al. in 2007,⁴⁶ Ruetten et al. in 2008,⁴⁴ and Jasper et al. in 2013.²⁰

Microendoscopic Surgery

In 1999 Foley (Fig. 2) et al. published their surgical experience treating far-lateral L3–4 and L4–5 herniated discs using a 25° rod-lens endoscope placed through a 16-mm-diameter tubular retractor.¹⁰ Instruments used in a traditional microdiscectomy procedure could now be applied under endoscopic visualization. The procedure was performed through an incision 5 cm off the midline. Mixer and Barr received credit for being the first authors to treat lumbar herniated discs by an open laminectomy and

discectomy approach.³⁹ With the introduction of the surgical microscope, Caspar and Yaşargil refined the open posterior approach, and they are credited with introducing the microdiscectomy procedure.^{2,57} Microendoscopic surgery offers several novel advantages over even the microdiscectomy procedure: the incision is smaller, the tubular retractor dilates and spreads tissue rather than destroying it, the paramedian approach spares the midline tension band, and endoscopic visualization allows the point of vision to be only a few millimeters away from the pathology due to the location of the camera lens, as opposed to the 20–50 cm that is the case with microscopic visualization.

Anterior Endoscopic Approaches

In the 1990s laparoscopic surgical techniques began to be adopted clinically; anterior endoscopic approaches were considered by some to offer possible advantages for the treatment of thoracic and lumbar disc disease.^{49,60} Laparoscopic lumbar discectomy was performed with an approach similar to laparoscopic abdominal surgery: pneumoperitoneum was established, and the small bowel and colon were retracted to provide access to the lumbar disc.^{49,60} A retroperitoneal laparoscopic lateral approach to the lumbar spine was also reported as a way to avoid laminectomy and disturbance of the facet.^{7,41} The disadvantages of peritoneal cavity retraction and the potential dangers of injuring the sympathetic chain, genitofemoral nerve, segmental lumbar arteries and veins, ureter, and superior hypogastric plexus made these approaches less feasible for widespread adoption.^{7,41}

Thoracoscopy and later video-assisted thoracoscopic surgery (VATS) were adapted for thoracic spine surgery in the early 1990s.⁴³ Reports have demonstrated the capacity of VATS to provide exposure for thoracic discectomy similar to that obtained with a transthoracic approach.⁴² However, in addition to a steep learning curve, the use of VATS for the treatment of thoracic spine disease is limited by the morbidity associated with working through the chest cavity.^{8,43} These limitations have hindered the widespread use of VATS for thoracic discectomy and have motivated the development of minimally invasive posterior approaches, including the endoscopic lateral extracavitary³⁶ and transpedicular approaches.²⁴

Innovations in Endoscopic Spine Surgery

The development of improved endoscopes and instruments, the increased experience of endoscopic spine surgeons, and the continued demand by patients for spinal surgery procedures that are as minimally invasive as possible have led to an explosion of innovation in endoscopic spine surgery. Published experience is available on transforaminal versus interlaminar endoscopic approaches,^{5,19,32} cervical approaches,⁵⁶ thoracic approaches,⁶ and approaches to the thoracolumbar junction,¹ as well as the treatment of far-lateral disc herniations,^{16,34,35} reherniations,^{13,45} extruded discs,^{3,21,54,58} spondylolisthesis,^{17,23} radiculopathy in the setting of instrumented fusion,^{51,53} discitis,¹⁴ discogenic back pain,⁵⁵ and spinal tumors.^{25,52} Other studies published include the treatment of geriatric²² and obese¹⁸ populations and the use of intraoperative MRI,⁴ lasers,³³ and interbody

fusion devices^{15,40} in endoscopic spine surgery. In the fields of nonendoscopic surgery (surgery performed with the naked eye, loupes, or a microscope) and endoscopic spine surgery, the spinal pathologies and goals of treatment are converging. The clearest difference in the two fields appears to be the method of visualization.

Direct Visualization

In order for an object to be “seen,” its image must be focused on the back of the retina. The retina is to the eye what film is to the camera. Endoscopic cameras allow us to move the “eye’s” lens remotely to the site of the surgical pathology. Two dramatic examples of the technological innovation that implements this simple idea can be seen in space exploration and military combat: unmanned probes on Mars and military drones in remote areas of conflict bring our eyes “directly” but remotely to the points of interest. Innovation enables us to work at such sites from a remote location. The history of endoscopic spine surgery is indeed brief, and although many around the world justly can take credit for its inception and early development, the greatest credit will always likely go to the surgeon for whom Kambin’s triangle is named.

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