South Denver Spine & ROBOTICS

SPINE Times

2017 / Fall

Contents:

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Combining the Advantages of Minimally Invasive Spinal Surgery and Robotics

Technological advances have always played a role in improving medical care. Everywhere in medicine, new diagnostic tests and therapeutic methods, which were not available a few short years ago, are routinely employed to combat disease processes. Common examples include x-rays giving rise to CT scans and eventually leading to highly specialized MRIs capable of discerning different tissue types within millimeters. Many coronary artery bypass procedures have now been supplanted by minimally invasive stents, some of which are capable of eluting medication to keep diseased vessels open.

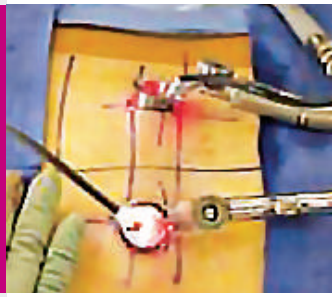
Spinal surgery has seen tremendous advances as well. In the nearly 20 years that I have been in practice, I have witnessed the development and implementation of many technologies which were either in their infancy or had not been thought of at the beginning of my career. Artificial disc prostheses are now commonplace (certainly in the cervical spine – see last Spine-Times). New biologics and stem cell technologies have been introduced to enhance fusion rates. Advances are also being made in replacing damaged nervous tissues with native tissues generated from these technologies. Surgeries which 10 years ago required extensive open dissection are now being safely completed through 2-3 cm incisions with minimal tissue disruption.

Most patients and physicians who are familiar with South Denver Spine are familiar with the comprehensive nature of spinal care offered by this practice. We have made great efforts to incorporate new technologies ranging from state of the art techniques for treating the deformed spine to developing a procedural suite specifically to perform in-office kyphoplasty. Many are also aware that a large part of my practice encompasses minimally invasive spinal surgery (MIS Surgery) and that over the last 10 years I have developed a special interest in robotically assisted surgery.

The combination of the last two items mentioned above deserves special mention. Advantages of minimally invasive spinal surgery (MIS Surgery) have now been well described in the literature and these techniques are being utilized more and more frequently worldwide. More recently, the advent of robotic surgery enables spinal specialists to place instrumentation into anatomic structures with accuracy measured within fractions of a millimeter. It is my personal belief that the blending of these exciting technologies leads to much shorter patient recoveries and outcomes that cannot be matched by traditional, open, freehand techniques.

In this Spine-Times, we will examine the rationale for the development of these exciting techniques, the advantages conferred by both, and how the combination of these techniques and technologies has led our practice to prominence.

Minimally invasive spinal surgery is spinal surgery which utilizes specialized tools and techniques which allow for much smaller incisions and less tissue disruption. Note the tubular retractor which is fixed to the table.

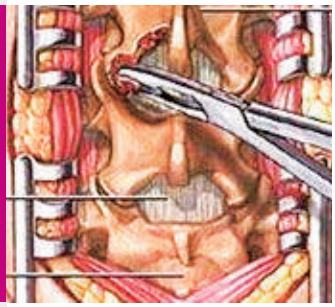


What is Minimally Invasive Spinal Surgery (MIS Surgery)

Minimally Invasive Spinal Surgery (MIS surgery) is a specialized form of surgery which was developed to minimize the "collateral damage" in spinal surgery by using specialized tools and techniques which allow for much smaller incisions and much less tissue dissection. Importantly, the surgical goal of MIS surgery is always the same as it is for a traditional open surgery. However, the methods of achieving that goal while minimizing tissue disruption may be significantly different.

Typically, MIS surgery involves limited dissection and decompression of nerves through a tubular retractor rather than a traditional open incision. Because the MIS surgeon is working through a much smaller exposure, specialized tools are required and hardware to be inserted is often coupled with long extenders which allow for precise manipulation though a very small approach. Finally, because direct visualization of anatomic structures is often limited by small incisions, MIS surgery is highly x-ray dependent.

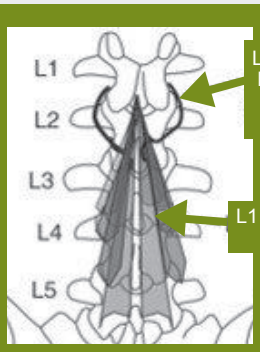
Traditional open surgery typically involves a large midline incision and "self-retaining" retractors. The muscle "stripping" and use of these self-retaining retractors has been demonstrated to be damaging to the muscles surrounding the spine.



Certainly, as these techniques advance, more and more patients and conditions are considered candidates for MIS surgery. However, MIS surgery currently comprises only 10-15% of all spinal surgeries. A major reason for this is that MIS surgery requires a completely different skill set than traditional open surgery. Many surgeons do not have sufficient training and expertise to truly perform MIS surgery. Nevertheless, as the medical literature continues to document the significant benefits of MIS surgery, more surgeons are being exposed to these techniques in their training or are learning these techniques while in practice by attending courses and being proctored.

Open Spinal Surgery vs. MIS Surgery

The Dimensions of back pain are staggering. Over 65 million Americans suffer from debilitating back pain on an annual basis. Overall, conditions causing back and leg pain comprise the third most common reason for elective surgery. As of 2014, over 500,000 lumbar laminectomies and 250,000 lumbar spinal fusions are performed in the United States annually.



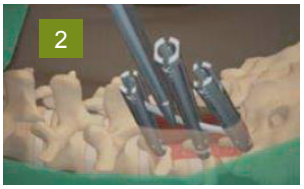
Multifidus.
The "stabilizer of the spine."

The majority of these spinal surgeries are performed using a traditional "open" approach. This typically involves a large, open midline incision with significant muscle "stripping" performed by the surgeon to access the bony structures and nerves housed within the spine. While sometimes necessary, the disadvantages of such an approach are numerous. Studies have shown that damage caused by this type of approach may often lead to nerve injuries resulting in muscle wasting which may frequently cause nearly as much back pain as these surgeries have intended to improve.

Typically, injury to back nerves and muscles occurs through three mechanisms. First, in a traditional open approach, muscles are typically "stripped" off the posterior part (back) of the lumbar spine. This technique serves the purpose of eliminating many of the origins and insertions, the anchor points, of the lumbar muscles. After surgery, these anchor points frequently remain compromised. This causes muscle to atrophy and become weaker.

Secondly, injury to the muscular sleeve occurs because of the use of "self-retaining" retractors. These retractors place substantial force against a very localized part of the

Specialized equipment is integral in the less disruptive minimally invasive method. Equipment frequently includes tubular retractors (1) to facilitate smaller incisions and hardware "extenders" (2) which allow manipulation through limited exposures.



retracted muscle. Several authors have demonstrated that this type of retraction serves to increase intramuscular pressure and decrease blood flow and oxygen supply to this area of muscle, permanently injuring it.

Finally, a major consequence of traditional, open surgery is that the nerves that supply the posterior muscles are often injured in the approach. This is especially important with respect to the Multifidus muscle. This small but stout and well-positioned muscle is considered the "stabilizer of the spine". The Multifidus is unique in that it derives its nerve supply from only one segment of the spine. Unlike the much larger muscles, the Longissimus and Iliocostalis, it is not innervated over many segments over the length of the muscle by many different nerves. Thus, this open dissection often leads to irreversible damage to this all-important "stabilizer of the spine".

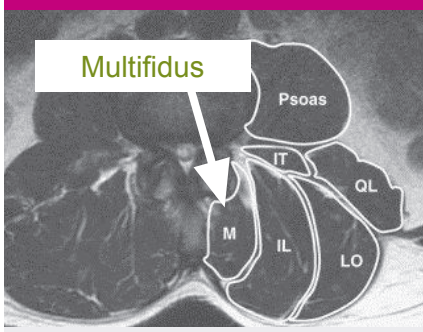
MIS surgery is designed to minimize the injury to this "muscular sleeve". Much smaller incisions are utilized and dissection is carried out elegantly through intramuscular planes, avoiding spinal muscular stripping. Tubular retractors enable a focused spinal approach while minimizing tissue disruption and avoiding increasing intramuscular pressure and disrupting blood flow. Finally, the more lateral (as opposed to midline) approach which utilizes intramuscular planes does not disrupt the nerve supply of the Multifidus. Indeed, post-operative MRI studies have indicated that this muscle remains robust and undamaged in MIS approaches while it is often severely atrophied in open approaches. This correlates significantly to preserved core strength and decreased pain after MIS surgeries as opposed to open procedures (Kim, 2005).

MIS Surgery– Proof of Concept

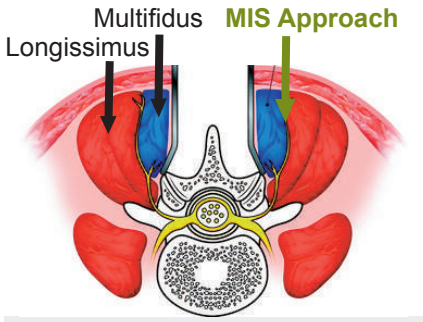
In addition to the above study, there has been mounting evidence in the literature of significant advantages offered by MIS surgery. A few short years ago, MIS surgery seemed like a "cool idea" but many presumed benefits were largely unsubstantiated. Certainly, benefits such as smaller incisions and less blood loss were readily apparent. But these advantages appeared to be minor in comparison to perceptions that the surgeon may not be able to "do as much" through a small incision, leading to concerns that nerve decompression may not be as complete as in an open technique. Other claims by MIS surgeons that their patients had less pain, faster recovery, and shorter time off work appeared to be true, but lacked basic literature support.

Over the last ten years, there has been a plethora of evidence in the literature documenting the safety, efficacy, and discrete advantages of MIS surgery in comparison to open spinal procedures. Arguably, this began in 2007 with another study by Kim published in Spine. In this study, the authors looked at bloodstream markers for tissue injury. Titers of creatine kinase, aldolase, and proinflammatory cytokines were measured at 1, 3, 7, and 14 days in 26 patients undergoing similar surgeries via either an open or MIS technique. The study demonstrated two to sevenfold increases in all markers associated with tissue injury in the open group versus the MIS group. Furthermore, these markers typically returned to baseline within 3 days in the MIS group vs. 7 days in the open group. This study was integral in demonstrating that tissue injury appears to be substantially decreased when an MIS approach is utilized vs. a traditional open approach.

The Multifidus is a small, stout muscle which is known as the "stabilizer of the spine". This muscle is the most medial of the spinal musculature and is most closely attached to the spine. As a result, it is most frequently and severely damaged during a traditional open approach.



The image depicts a classic open approach involving muscular stripping. Rather than stripping the spinal muscles off the spine, minimally invasive spinal surgery typically exploits the interval between the Multifidus and the larger adjacent muscle, the Longissimus.



MIS surgery traditionally utilizes a "two C-arm technique". This cumbersome method is necessary in order for the surgeon to simultaneously visualize the spine in the AP and lateral planes.

Two very similar clinical studies were published by Adogwa and Parker, respectively in 2011 and 2012. Both studies compared outcomes for equal numbers of patients undergoing open vs. MIS surgery for the same diagnosis – degenerative spondylolisthesis. Both studies came to the same conclusion.

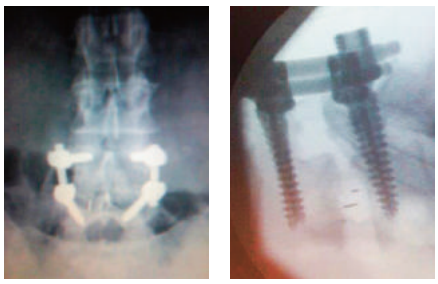
Adogwa was published in the Journal of Spinal Disorders. His study was a retrospective comparison of 15 patients undergoing MIS surgery with 15 patients undergoing open surgery. His findings demonstrated that patients undergoing MIS surgery had a significantly shorter hospital stay (3 days vs. 5.5 days), stopped using narcotics sooner (2 weeks vs. 4 weeks) and returned to work in less than half the time (8 weeks vs. 17.1 weeks).

Parker's study was published in World Neurosurgery. He prospectively compared 50 patients in each group. His findings were very similar. Patient hospital stays averaged 2 days in the MIS surgery group vs. 4 days in the open group. Likewise, he found that MIS surgery patients returned to work at an average of 6 weeks vs. an average of 11 weeks in the open group. He went further and demonstrated a significant cost savings in using the MIS technique.

One final study, also performed by Parker, deserves mention. A devastating complication of any type of spinal surgery is that of infection. In a 2011 study published in The Journal of Minimally Invasive Neurosurgery, Parker published a meta-analysis of the literature looking specifically at incidence of infection. His findings were impressive. As expected, because open surgery has been an accepted technique for much longer, he was able to find many more articles pertaining to infection in open spinal surgery. He found 20 studies comprising 1133 patients in the open group vs. 10 studies and 362 patients in the MIS surgery group which met his criteria. Nevertheless, in this well-done study, Parker found the incidence of infection in the open group to be 4.0% vs. only 0.6% in the MIS surgery group.

The information presented above includes studies which I believe have been integral in demonstrating the advantages of MIS surgery and bringing it into the mainstream of spinal surgery. While some of these studies are slightly dated, the overwhelming abundance of newer literature has been as supportive, if not more so. Importantly, surgeons have only improved upon their techniques. Some of the numbers quoted above are rare in today's experience. For example, it is a rarity for a patient undergoing a single level MIS fusion to stay in the hospital for more than one day. Likewise, the clear majority of patients return to work well before the 6-week mark.

In any case, at this point in the MIS surgery experience, it is fair to say that many of the proposed advantages of this type of surgery have been confirmed. Not only may MIS surgery be performed safely through smaller incisions with less blood loss, MIS surgery patients appear to incur significantly less tissue damage and have improved outcomes in comparison to open surgery. Also, patients who undergo MIS surgery appear to recover substantially faster after surgery and return to work in less time. These patients also have diminished usage of post-operative pain medications and less post-operative complications (specifically infections).



AP and lateral C-arm images of the spine obtained using the two C-arm technique.

That's not to say that MIS surgery doesn't have its limitations. A major limitation of MIS surgery is that of surgeon experience. It is estimated that MIS surgery comprises only about 15% of all spinal surgery. A big reason for this is that many surgeons were not exposed to MIS surgery in their training and are not comfortable with it. An MIS surgeon must be facile with many non-traditional surgical techniques. Included amongst these is the ability to manipulate instrumentation through small incisions using x-ray (or guidance) without directly seeing the surgical target. These skill sets are acquired only through extensive experience and practice.

Another potential limitation of MIS surgery is the cumbersome nature of the equipment required. Because direct visualization is limited – a function of smaller incisions and less dissection, MIS surgery relies significantly on imaging to accurately place instrumentation into the human spine. Classically this imaging is acquired using C-arm (portable x-ray) machines. In order to accurately place instrumentation in the human spine it is necessary for the surgeon to simultaneously visualize a patient's spine in two perpendicular planes. For this reason, two C-arms are typically utilized simultaneously. This set up is not without its issues. The C-arm machines are large and often occupy valuable space in the operating room. The patient and operating team are frequently exposed to excessive radiation. Finally, in large or stocky patients, underlying anatomy may be difficult to identify with this technique because of insufficient x-ray beam penetration, making hardware malpositioning a very real possibility.

Mazor Surgical Platform In use.

The Role of Robotics – Increasing Accuracy

Computer-assisted guidance systems now play an integral role in many spinal procedures. These technologies take many forms and provide assistance to the surgeon in ensuring accurate placement of instrumentation. This is typically done by allowing the surgeon to develop a pre-operative "blueprint" of the surgery to be performed using a scan of the patient's spine. The surgeon is then able to utilize the blueprint intraoperatively to accurately place instrumentation during the surgery.

Robotic surgery is a form of computer-assisted guidance in which a robot directly assists the surgeon in accurately placing instrumentation. Mazor Robotics is the industry leader in robotic spinal surgery. Currently, three systems are available in the Denver Area. Parker and Littleton Adventist Hospitals have the Mazor Renaissance system. Sky Ridge Medical Center has the newer Mazor X Surgical Assurance Platform. Our practice is the community leader in having performed nearly 400 robot-assisted spinal surgeries, as of January 1, 2017. This is nearly 375 more than any other Denver spinal practice!

The Mazor Renaissance guidance system.

The Mazor robotic systems are truly unique systems which differ significantly from other guidance technologies. Using these systems, the surgeon is able to virtually position instrumentation at the preoperative stage (as opposed to using the preoperative imaging to guide positioning intraoperatively). These systems are currently the only FDA-approved mechanical guidance systems for spinal surgery and typically enable the surgeon to place hardware within a 1mm margin of error.

The Mazor systems utilize a four-step technique in accurately placing instrumentation. The first step occurs preoperatively. The remaining three steps occur in the operating room during surgery.

The Mazor X Surgical Assurance Platform.

The first step is the preoperative plan and involves forming the surgical "blueprint". In this step, a preoperative CT scan of a patient's spine is obtained and uploaded to the computer. Using the Mazor software, the surgeon can virtually place instrumentation into the spine and confirm accurate position in all three planes. In the second step, the Mazor device is rigidly attached to the patient and a fiduciary optical array is attached. The rigid attachment of the device is essential in confirming accurate placement. In step three, two C-arm images (one AP and one oblique) are obtained of the patient's spine with the fiduciary array in place. The computer is

An important part of utilizing the advanced Mazor Robotic Guidance Systems is the preoperative formation of a "surgical blueprint". This allows the surgeon to preoperatively place all instrumentation into the patient's spine in a virtual environment. The robotic guidance system then allows precise operative placement of all instrumentation according to the blueprint.

then able to use these C-arm images in conjunction with the superimposed fiduciary array to merge the patient's anatomy with the preoperative CT scan, synchronizing the preoperative "blueprint" with the position of the patient's anatomy on the surgical table. Finally, in step four, the Mazor robot is utilized to precisely guide the surgeon to the position of underlying anatomic structures. The Mazor uses the combined and integrated data from the preoperative CT scan along with that gleaned from the C-arm images to allow exact placement of surgical hardware.

The advantages of this technologically advanced system are considerable. Multiple studies (see sidebar) have demonstrated significantly increased accuracy in placement of instrumentation in comparison to traditional techniques. Decreases in complications from malpositioned hardware have been demonstrated. Surgical time has decreased considerably and been standardized. Difficult or hard to see anatomy is no longer a cause for a prolonged patient "time under anesthesia". Finally, and perhaps most importantly, surgeon confidence in appropriate placement of hardware, even in the most technically challenging of circumstances, has been dramatically improved.

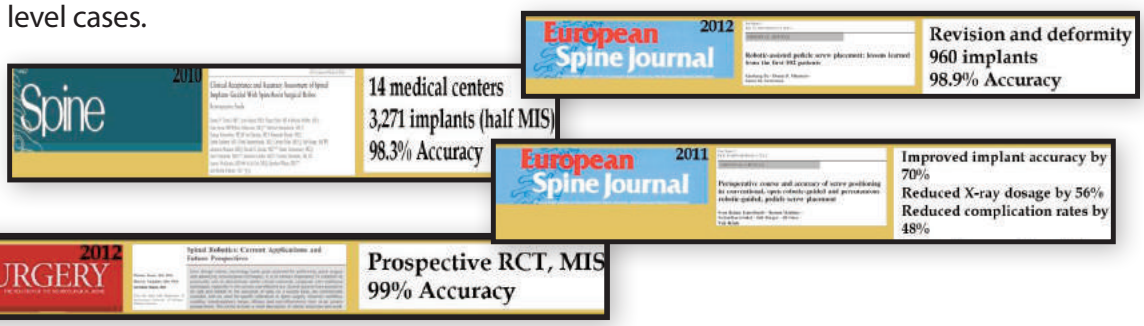
Merging Minimally Invasive and Robotic Technologies

While the Mazor Robotic platform is useful in all types of spinal surgery, in no area is this technology more helpful than in that of MIS surgery. Numerous studies have demonstrated significantly increased accuracy in placement of instrumentation using the Mazor guidance system in comparison to freehand techniques, especially in MIS surgery cases. Decreased hardware related complications have also clearly been demonstrated.

The Mazor system reliably allows the surgeon to place instrumentation with an accuracy of within 1mm of its intended target. This is far better than any freehand technique or any technique utilizing standard C-arm imaging. This increased accuracy is extremely helpful in the case of minimally invasive spinal surgery, where visualization is already compromised. The Mazor allows the MIS surgeon much more confidence in accurate placement of instrumentation and the ability to operate more comfortably and confidently by removing the cumbersome C-arm machinery utilized to define patient anatomy.

In a technique developed and patented by SDS, a "working side" and a "non-working side" of the spine is designated based upon the patient's symptoms and anatomic constraints. The Mazor is utilized at the very beginning of the case to localize the spinal pedicles (the anatomic structures which will accept instrumentation). This is typically performed through two 3cm incisions on either side of the patient's spine. The hardware is then placed on the "non-working side" while decompression of the spinal nerves is performed from the "working side". At the conclusion of the case, the instrumentation is placed on the "working side". The construct is secured and the wounds are closed. Typically, the length of the case is about 1-1/2 to 2 hours for a one level MIS fusion and 3 to 3-1/2 hours for a case which spans two or more levels. Patients are typically discharged from the hospital the following day for one level cases and between one and two days for multiple level cases.

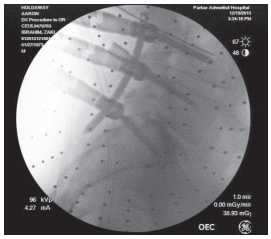
Multiple studies have demonstrated increased accuracy and decreased complications using the Mazor Guidance Systems in spinal surgery.

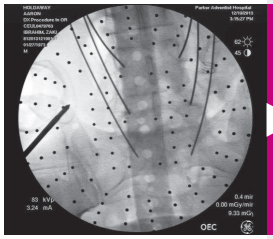


And in Conclusion . . .

A surgeon utilizing the Mazor X Surgical Assurance Platform to precisely place instrumentation. Note that he has significantly more space than the surgeon utilizing the two C-arm technique (page 4).

The two emerging technologies discussed in this SDS publication are taking their place in the field of spine surgery for very valid reasons. The true advantages of MIS surgery have been clearly documented. Undoubtedly, MIS procedures are less invasive to the patient. Faster recoveries and return to work, less post-operative pain, a lower infection/complication rate and less internal tissue trauma are among the myriad of reasons to consider these promising technologies. Prior concerns about the adequacy of nerve decompression through a limited approach have fallen by the wayside as study after study has demonstrated equivalence with the open technique in this regard. My experience in my personal practice has mirrored that seen in the literature. In short, while traditional open surgery has been the standard for many years, the tide is changing. The benefits of MIS surgery now far surpass those of the traditional open technique.





Accurate placement of instrumentation utilizing a Mazor Robotic Guidance System.

Likewise, robotic spinal surgery is proving to be a game-changer. Significant advantages of this technology include increased accuracy in instrumentation placement, decreased hardware-related complications, and decreased patient surgical time. The category-leading Mazor guidance systems are now available at three area hospitals. Certainly, this is an indicator of the high local community standards in medical care and the willingness of these medical centers to adopt "cutting-edge" technology.

South Denver Spine is unique in the community in that we are the only spine-specific practice that has combined the advantages of MIS surgery with robotics. The number of practitioners in the community who truly practice MIS reflects the national average – about 15%. Only a handful of spinal surgeons in the community have embraced the Mazor technology, despite its demonstrated benefits. No other practice has routinely combined these two promising technologies although various physicians have dabbled.

Our Mission Statement at South Denver Spine is as follows: "To provide our patients with compassionate care and exceptional outcomes using leading edge techniques and technology". True to this statement, as a team, we work hard to see that our patients have exceptional outcomes. Integral to our approach is a willingness to research and incorporate new technologies, when appropriate, regardless of the difficulty which may be encountered in doing so. This is not common practice among surgeons, many of whom use surgical techniques, with minor modifications, taught to them many years ago.

At this point, there is no doubt about the individual benefits of minimally invasive spinal surgery and of robotic spinal surgery are real. Combined, the benefits of these techniques are compounded. We are proud to be the only practice in Denver that currently offers our patients the advantages of these techniques combined. We hope that you consider South Denver Spine when making a referral for a patient with a spinal problem.

About the Author

Dr. Zak Ibrahim is a board-certified, fellowship-trained spinal surgeon who practices at South Denver Spine, PC. Dr. Ibrahim's expertise encompasses management of all spinal disorders ranging from complex spinal deformity and revision surgery to new, minimally invasive techniques. He has written and published several peer-reviewed papers and book chapters in his specialty.

Dr. Ibrahim embraces a conservative, open-minded approach to treating all spinal disorders. He is extremely interested in the development of new surgical technology as well as in physician and patient education about this technology. If you are interested in receiving South Denver Spine~Times electronically, please visit us at SouthDenverSpine.com.

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South Denver Spine & ROBOTICS

Meet Our New Doctor

LARRY LEE, M.D.

A Boston native, Dr. Larry Lee studied Biology at Washington University in St. Louis, where he competed as a college athlete with the crew team. He received his medical degree from Drexel University College of Medicine in Philadelphia. While at DUCoM, he was involved in medical policy as the medical student representative to the Pennsylvania Medical Society and in his "spare" time, he volunteered at free clinics in the community. It was during this time that he developed his love for orthopaedics. He returned to Boston to continue his training at Tufts Medical Center as an orthopaedics resident. While orthopaedic trauma and joint replacements were exciting opportunities, spine surgery ultimately drew him in. Dr. Lee pursued this love of spine surgery by completing his fellowship in Spine Surgery at the University of Southern California in Los Angeles. This unique opportunity allowed him to train under the direction of both world renowned orthopaedic and neurosurgery spine surgeons. Cross-trained in various subspecialties of spine, he is particularly focused on spinal deformity and minimally invasive surgery. In his time off, he enjoys hiking and is an avid runner, having completed 7 marathons and countless other road races.

Spine~Times is published by Dr. Zak Ibrahim of South Denver Spine, PC, to bring the latest spinal news and information to physicians and patients throughout the Denver metro region.

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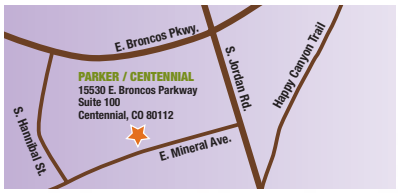

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