3 IMAGING METHODS IN MINIMALLY INVASIVE SPINE SURGERY

Erdal Coskun MD

With the improvement of assisting imaging methods and the continual evolution of surgical instruments and ecarteur, popularity of minimally invasive spinal surgery has increased in the last years. Basic X-ray, C armed scope, CT (computed tomography), MRI (magnetic resonance imaging), USG (ultrasonography) and navigation can be used for imaging during these attempts.

Spinal Navigation

Spinal navigation systems have been behind of cranial navigation due to inexistence of stable reference point. It has become the main imaging method with the software improvement that decreases the error rate. It is apparent that error rate will be lower in navigation systems for cranial because of deviation of anatomy with CSF drainage and calibration with real time scope. In the last years, software that will integrate patient's MRI and CT images to systems during surgery has been developed. As a consequence, incision length can be decreased with this technique, instrument usage can be safer, and operation time can be shorter.[7,9,18] If we assume that spinal surgery is the major operation in neurosurgery, these techniques that decrease medico-legal problems, error rates and operation time thus making these methods more popular. (Figure 1a, b)

Robotic Systems

Together with the development of navigation systems, robotic systems are introduced. CT based 3

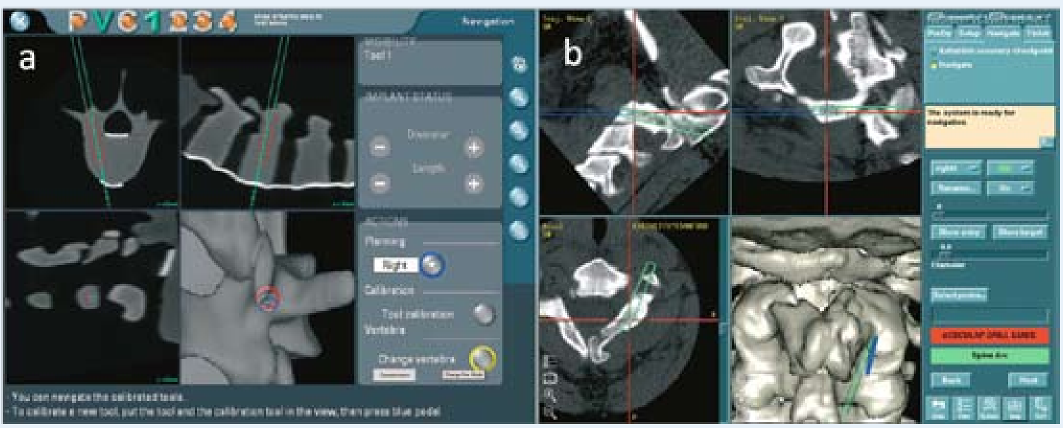


Figure 1: *Screwing with navigation on* **(a)** *lumbar and* **(b)** *cervical*

dimensional planning provides decreased incision length and optimization of instrument placement. It also warns the surgeon for anatomical differences and decreases the complication rate. In addition, it quickens the learning of percutaneous systems. Furthermore, it decreases the hospital stay length and cost. Also, one of its advantages is that it does not occupy a lot of space and X ray dosage is lowered for the surgical crew. (Figure 2)

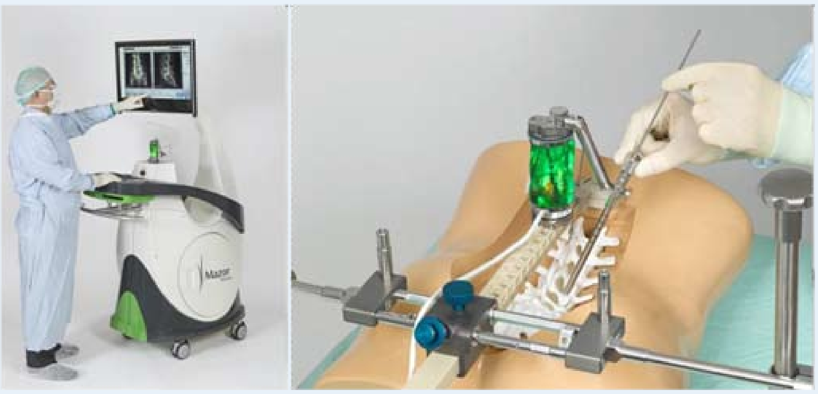


Figure 2: *Robotic screwing system added to spinal navigation*

Magnetic Resonance Imaging

Important information about spinal fractures and timing of them is acquired from STIR (short tau inversion recovery), a new MRI technique that is used in the preoperative period, which suppresses fat. Furthermore, it provides information during vertebroplasty about the fracture line, which will be filled with cement on T2, weighted cross sections. MRI also gives detailed information about fluid injection or gadolinium use after discography. It gives sufficient support to minimally invasive surgery by providing detailed images and making it safer for the diagnosis and treatment of tumors or degenerative disc diseases.[7,8,16]

Computed Tomography

CT is mostly used during spinal biopsies and discographies during surgery. Robertson and Ball first did percutaneous spinal biopsies in 1935 without a scope.[14] Siffert and Arkin [17] did spinal biopsy with conventional imaging. First biopsy with the assistance of scope was done in 1969, and with CT was done in 1981.[1,10] Using CT during surgery decreases the adjacent tissue and vein injury and provides safer pathological samples from the area that is needed. Three-dimensional images from CT pioneered in diagnosis as well as surgical planning and have been a milestone for minimally invasive surgery. An important complication of biopsy, tumor plantation on the surgical line, is much lower with CT than with scope.[2,8,9] Using CT during ablative attempts for pain (facet denervation, epidural blockage, SI injections) increases the strength and safety of the procedure.[11,15] However, this area is also passed on to invasive radiologists and algologists.

C-Armed Scope

Most of minimally invasive interventions require scope guidance, for this purpose, this section is about scope utilization in detail. C-armed scope can reach to aimed anatomical region by using several images acquired from different angles. Rigid scopes used for gastrointestinal purposes are insufficient. Motorized scopes used by invasive neuroradiologists can maximize the image quality while minimizing error rate. Procedure time and exposed radiation can be decreased with these motorized systems and experienced staff. Device can put recurring procedures to its memory, and with the use of appropriate software operational steps can be shorter. However, the rooms, which have these devices, are usually not convenient for routine surgeries.[4,8,11,15]

Operation table should be permeable to beam and relatively narrow for C-armed scope's motion. Material to keep patient's position stable should not block the image and C arm should be wide. Side of the C arm is not important. Sterile cover must be adjusted to allow scope's motion for 90 degrees. Most C armed scopes have laser for guidance purposes.[4,8]

Beam Safety

In order to protect from hazardous properties of radiation, preventive gloves, preventive lead scrubs and preventive thyroid materials must be used and taught. Most surgeons usually neglect these steps due to the weight of the material and its restricting features. However, the surgeon is not only putting himself at risk, but also affects other staff as well. The assisting personnel can expose surgeons to charges in the future. Equipment that will be used for C armed scope should have low scatter gram and pulse mode skill. By using approximately 4 pulse/s mode, radiation exposure can be decreased at least 80% with real time scope.[4]

Using Scope on other Areas

Using scope for minimally invasive approach made surgical techniques improve and decrease surgical extent.

Scottie dog view provides appropriate aim points for all lumbar injections (entry for transforaminal epidural, intralaminar epidural, intraarticular facet injections, medial branch injection, discography or intradisc procedures).[11,12,15,16,19] It is obtained by rotating the scope 20-30 °. More rotation is needed for lower lumbar facet injections. (Figure 3)

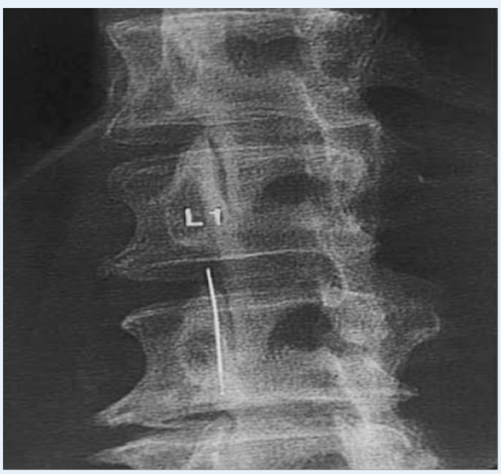


Figure 3: *Scottie dog view obtained by rotating scope by 20-30o*

Epidural anatomy is shown with **epidurography,** and it also prevents medication to escape to thecal sac or veins. Patient can be in prone, sitting or lateral decubitus position. C armed scope is rotated to lateral and caudal by 20 and 30º, respectively from the midline. Needle is guided to lamina's upper margin and then interlaminar space. There is a resistance while passing ligamentum flavum, and negative pressure is apparent in the epidural space. Contrast material is easily passed into epidural space.[11,15,19] (Figure 4) Epidurography is done with non-ionic contrast agent, which is proven safe for myelography. Contralateral oblique view is the safest for showing needle passing from lamina to space.

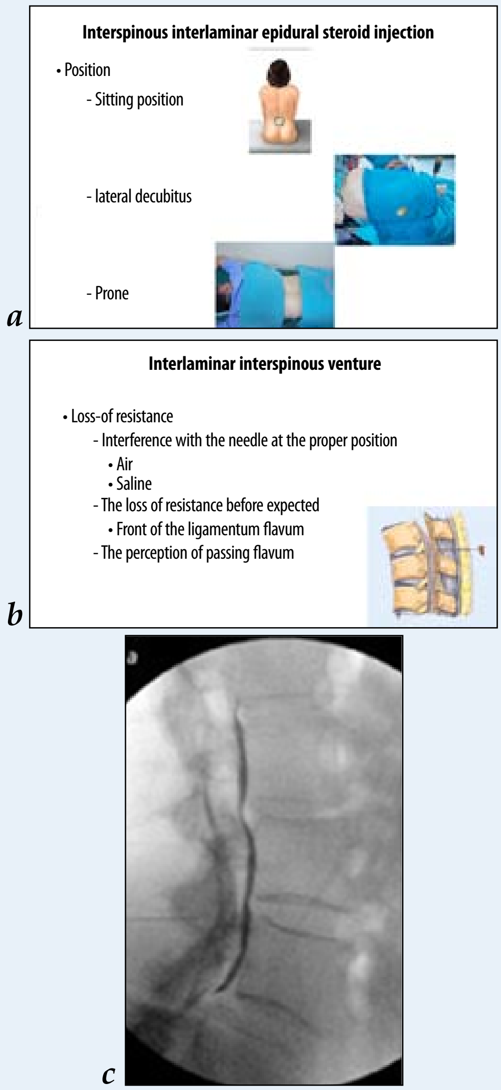


Figure 4: *Epidurography (a) position (b) inserting the needle (c) contrast agent injection*

Transforaminal epidural injection is done when the patient is in prone position. Lateral angle is more than in the interlaminar technique. Usually there is a 30-45° angle from the midline while mildly rotating to caudal position. Needle is guided to pedicle's lower margin and lightly medial. [11,12,15,19] Contrast agent is injected here, and it becomes dense around nerve sheath's proximal by leaking. (Figure 5)

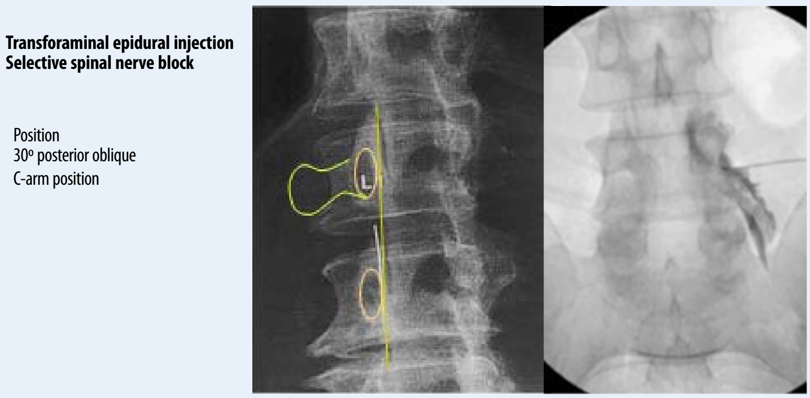


Figure 5: *Transforaminal epidural injection*

During **facet injection,** scope is given a slope that will be parallel to facet surfaces. This slope is less oblique in thoracolumbar junction than in lumbosacral. Needle is placed until the middle of the joint, and scope is rotated laterally to give a better view of this area. Entrance is posterolateral to a prone positioned patient. For **medial branch injection**, aim is transvers process' medial and superior articular process junction. Scottie dog view is obtained in oblique imaging, with this way entrance is safer while aiming transvers process and superior articular process' junction. For lateral imaging, needle should be behind neural foramen.[11,12,15,19] (Figure 6)

Because cervical facet joint is angled on superior to inferior, entrance is done from posterior and inferior to a prone positioned patient. Scope direction is caudocranial. Consequently, lateral mass and facets are visible. It is guided 2 cm lower than facet and then above. Also on **cervical medial branch injection**, patient is positioned supine and facet's image is taken mediolaterally. 20-30° oblique images are needed to see foramen and avoid there.

For **lumbar discography** various techniques are described. Patient is on prone position in order to lessen lumbar lordosis. With supports that will not block the beam, maximal space is obtained on the disc space and C armed scope is guided through 30-45° lateral from midline and 10-45° cranial. Actually these angles vary depending on the spinal levels. Orientation of imaging is obtained by giving craniocaudal angle on L4-5 and L5-S1 levels. For the discs that are above L3-4, usually angle is lowered for the scope. In order to obtain Scottie dog view, scope's direction is turned to lateral without changing orientation. Angle should be parallel to the disc, far from nerve and able to reach to disc's central. Appropriate angle is

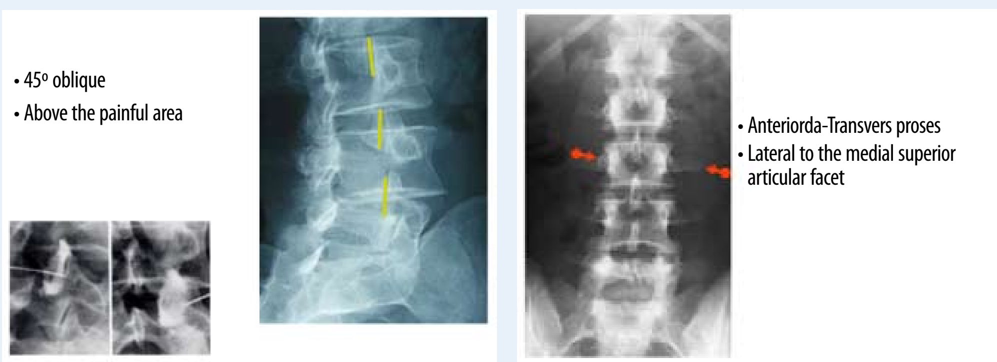


Figure 6: : **(a)** *appropriate entrance angle for facet joint blockage* **(b)** *medial branch injection*

obtained when the scope is between superior articular process and disc's 1/3 distance. Thus, scope is far away from oblique descending nerve.[11,15,16,19] Needle position is between clockwise 12 and 3 for the ideal positioning. (Figure 7)

Dorsolateral approach might be difficult in a patient that had fusion or instruments. In this case, median or paramedian transdural approach can be made. Scope is not needed continually while the needle is advanced. Millisecond scopes behind preventive scrubs are safer for the operator. Convenience of the position is checked with AP and lateral scopes after needle is advanced towards disc's center. Ideal position is when needle is in the center of the disc.

Thoracic discography is quite hard. Operation tables and scope systems that are used during angiography can be used instead of C armed scope. Needle usually needs to be 15-30° on AP image. Lower and middle thoracic area images are easier and safer to get. Obtaining images from T5-6 and above can be impossible at times. If no appropriate image can be obtained for upper thoracic area (lateral T1-4, due to shoulders being a part of the image) for wide patients, alternative-imaging methods should be considered.

For **cervical discography** patient's shoulders should be raised on supine position, head should be extended and directed to opposite of the procedural side. Needle is directed approximately 30-45° oblique and downward. Disc surfaces should be parallel for the scope. Needle is inserted between left index and middle fingers while they palpate the vertebrae. These fingers also hold carotid artery on the lateral side.[16,19]

For **arthroscopic discectomy** 11-12 cm, for discography chemonucleosis and vertebral biopsy 7-9 cm, for interlaminar approach 2-5 cm entrance is chosen. Entrance angle and place is safer to plan with CT. Needle is inserted with AP oblique and lateral scopes. Convenient localization on lateral image can show a dangerous position for AP annulotomy. It can be enough to have needlepoint vertically on AP image; however, vertical positioning on lateral image cannot be accepted. If the needlepoint is close to horizontal on lateral image, it means that the point is behind the vertebrae corpus; nevertheless, on AP image the point can be seen in the space. Safer approach is to have needlepoint on corpus posterium on lateral image and mid peduncular or lateral to pedicle on AP image. Where the pedicle divides into 3, medial peduncular line should be aimed for entering into the canal and removing sequestrum pieces; as mid peduncular line is aimed for foraminal discectomy and arthroscopic discectomy and lateral peduncular line for discography and extra foraminal discectomy. Kambin triangle is used for arthroscopic discectomy. This triangle is formed by superior articular process on middle, superior

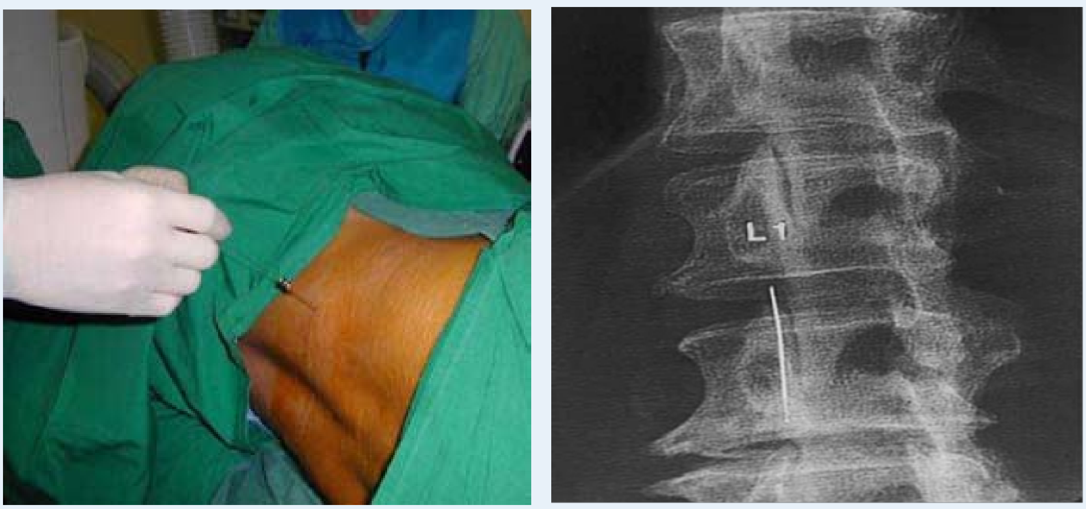


Figure 7: : *Discography* **(a)** *position* **(b)** *appropriate angle is obtained when facet joint's half and 1/3 crosses*

end plate on below and nerve on superior lateral.[4,5,6,15,16,19] (Figure 8)

Injection to **sacroiliac joint (SI)** can be done with CT, C armed scope, MRI or USG. The patient is put to prone position and the scope is shifted to 15-30° from middle to lateral while joint's lower 1/3 surface is parallel. 20-30° of angle is given cranially. If CT is being used, 3-5 mm slices are obtained. Same procedure can be done with USG under experienced hands.[11,13,15] (Figure 9)

Transpedicular approach is the main procedure for vertebroplasty and percutaneous screwing. Patient

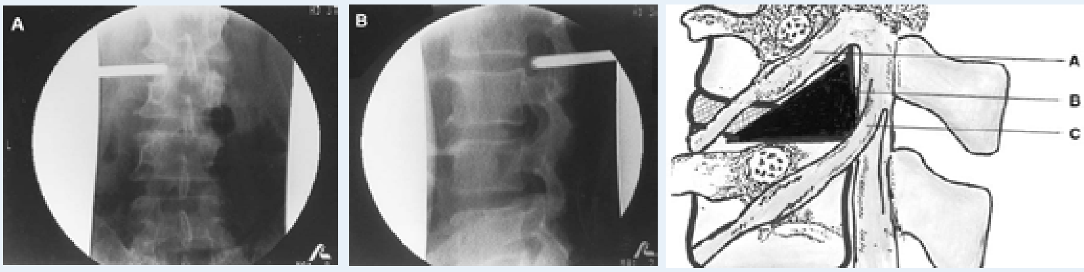


Figure 8: : *Arthroscopic discectomy* **(a)** *AP* **(b)** *lateral scope*
(c) *Kambin triangle and adjacent neural structures A upper margin B dural sac C lower nerve*

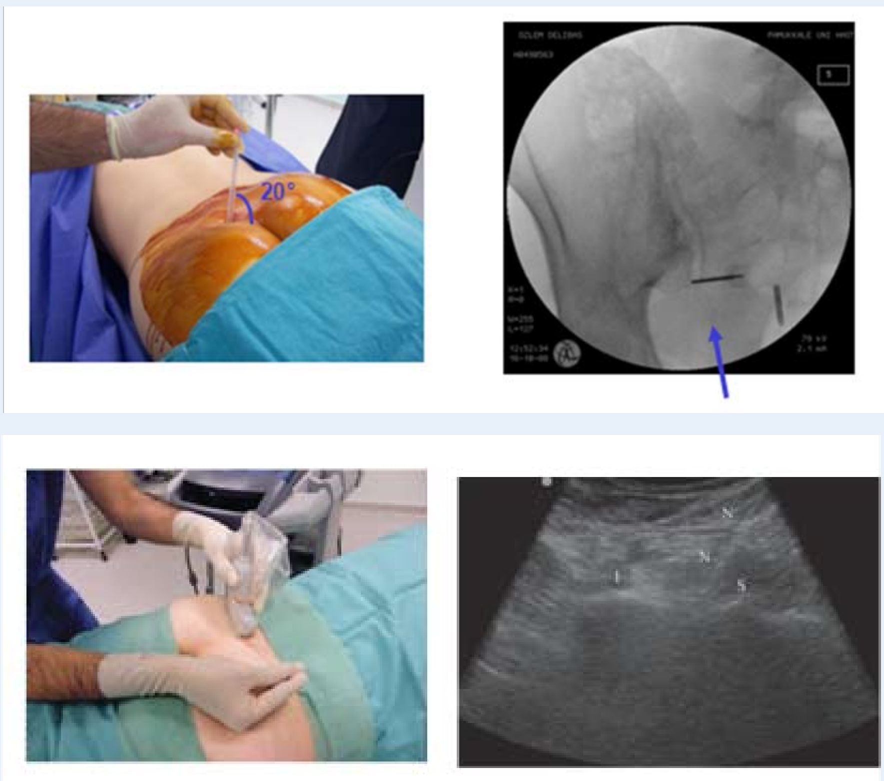
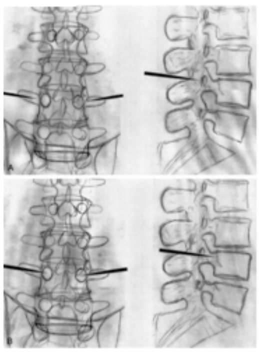


Figure 9: : *SI injection* **(a)** *position (b) scope view and needle entrance when joint's lower 1/3 surface are parallel (c) SI injection with USG*

is given slight lordosis position. Entering into peduncle is safer with CT. Although it has gained popularity for vertebroplasty and kyphoplasty, cement injection is used less due to not being enough safe for follow-up. Approach starts from peduncle's lateral and superior margin after achieving bull's eye view on AP image. Entrance through skin is 2.5 cm upper and 2.5 cm lateral of this view. Needle is put through clockwise 2-3 for the right side, and clockwise 9-10 for the left side. [2,3,9] (Figure 10)



• The fluoroscopic image should be obtained from beam which perpendicular to the spine.

Figure 10: *Transpeduncular entrance*

References

1. Adapon BD, Legada BD, Lim EVA, et al. CT-guided closed biopsy of the spine. J Comput Assist Tomogr 5:73–78, 1981
2. Hadjipavlou AG, Kontakis GM, Gaitanis I, Tzermiadianos M. Diagnostic and Therapeutic Percutaneous Transpedicular Approaches to the Spine. Chapter 8. Arthroscopic and Endoscopic Spinal Surgery Text and Atlas, Second Edition Ed: Parviz Kambin, Humana Press Inc. 2005; 167-204.
3. Hess GM, Mayer HM. Percutaneous Vertebroplasty in Osteoporotic Vertebral Fractures chapter 25 H.M. Mayer (Ed.) Minimally Invasive Spine Surgery A Surgical Manual Second Edition Springer-Verlag Berlin Heidelberg. NewYork 2006; 222-229
4. Kambin P. Instruments and Surgical Approaches for Minimally Invasive Spinal Surgery Via Posterolateral Access. Chapter 3. Arthroscopic and Endoscopic Spinal Surgery Text and Atlas, Second Edition Ed: Parviz Kambin, Humana Press Inc. 2005; 49-60.
5. Kambin P. Arthroscopic and Endoscopic Spine Surgery via a Posterolateral Approach. Chapter 37. H.M. Mayer (Ed.) Minimally Invasive Spine Surgery A Surgical Manual Second Edition Springer-Verlag Berlin Heidelberg NewYork. 2006; 331-345
6. Krugluger J. Transforaminal Endoscopic Discectomy. Chapter 35. H.M. Mayer (Ed.) Minimally Invasive Spine Surgery A Surgical Manual Second Edition Springer-Verlag Berlin Heidelberg NewYork. 2006; 315-321.
7. Langlotz F, Nolte LP. Computer-assisted Minimally Invasive Spine Surgery – State of the Art Chapter 6. H.M. Mayer (Ed.) Minimally Invasive Spine Surgery. A Surgical Manual Second Edition Springer-Verlag Berlin Heidelberg NewYork. 2006; 26-31
8. Mathis JM. Materials Used in Image-guided Spine Interventions. Chapter 2. John M. Mathis, Image-Guided Spine Interventions. Springer-Verlag Berlin Heidelberg NewYork. 2004; 27-36.
9. Ortiz AO, Zoarski GH. Image-Guided Percutaneous Spine Biopsy. Chapter 5. John M. Mathis, Image-Guided Spine Interventions Springer-Verlag Berlin Heidelberg NewYork. 2004; 69-93
10. Ottolenghi CE. Aspiration biopsy of the spine. Am J Bone Joint Surg 51:1531–1544, 1969
11. Reynolds J, Kine G. Minimally Invasive Techniques in Pain Management chapter 14 Arthroscopic and Endoscopic Spinal Surgery Text and Atlas, Second

Edition Ed: Parviz Kambin, Humana Press Inc. 2005; 271-294.

12. Rizk NN, Appaswamy M. Facet Blocks. Chapter 51. Peripheral Nerve Blocks: A Color Atlas, 2nd Edition Ed Chelly JE Lippincott Williams & Wilkins Philadelphia 2004.

13. Rizk NN, Carvelli AJ. Sacroiliac Joint Injection. Chapter 57. Peripheral Nerve Blocks: A Color Atlas, 2nd Edition Ed Chelly JE Lippincott Williams & Wilkins Philadelphia 2004.

14. Robertson RC, Ball RP. Destructive spine lesions: diagnosis by needle biopsy. J Bone Joint Surg 57:749–758, 1935

15. Schäufele MK. Interventional and Semi-invasive Procedures for LowBack Pain and Disc Herniation. Chapter 28. H.M. Mayer (Ed.) Minimally Invasive Spine Surgery A Surgical Manual Second Edition Springer-Verlag Berlin Heidelberg. NewYork 2006; 249-259.

16. Schellhas KP. Discography. Chapter 6. John M. Mathis, Image-Guided Spine Interventions. Springer-Verlag Berlin Heidelberg. New York 2004; 94-126

17. Siffert RS, Arkin AM. Trephine bone biopsy with special reference to the lumbar vertebral bodies. Am J Bone Joint Surg 31:146–149, 1949

18. Singh K, Fitzhenry LN, Vaccaro AR. Frameless Stereotactic Imaging Techniques in Minimally Invasive Spine Surgery chapter 17Arthroscopic and Endoscopic Spinal Surgery Text and Atlas, Second Edition Ed: Parviz Kambin, Humana Press Inc. 2005; 335-350.

19. Willis KD. Diagnostic Epidurography and Therapeutic Epidurolysis. Chapter 10. John M. Mathis, Image-Guided Spine Interventions. Springer-Verlag Berlin Heidelberg. NewYork 2004; 171-202.