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# Minimally invasive spine surgery in spinal infections

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**Infections of the spine have been a constant throughout history. At present there are infections in the spine fostered in part by the same advances in medicine: there are a lot of immunocompromised patients, the life expectancy of patients with chronic diseases is augmented and the increasing number of complex spinal surgeries can result in secondary infection. In this review the main types of infection of the spine and its treatment highlighting techniques in minimally invasive surgery are discussed. Spontaneous pyogenic and nonpyogenic spine infections as well as iatrogenic infections can be treated in a different manner depending on its extension, location and microorganism involved. We will review the use and the indication of percutaneous image-guided techniques, endoscopic and microsurgical techniques with or without use of tubular retractors. We conclude that techniques in minimally invasive surgery in spine infections are safe, effective and have benefits in morbidity of the approach and subsequent patient recovery.**

**KEY WORDS:** Spine - Surgical procedure, minimally invasive - Epidural abscess - Discitis.

Infections of the spine have been a constant throughout history.[1] In the present the incidence of pyogenic spinal infections is increasing for advances in medicine with more immunocompromised patients and chronic diseases, the acquired immunodeficiency syndrome (AIDS) pandemic and intravenous drug abuse.[2] Because a large proportion of patients will have a significant comorbidity is very important that if surgery is needed this one must be the less aggressive possible. This is one of the reasons why in the last years minimally invasive surgery has been increasing in the treatment of spinal infections.

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## Spontaneous pyogenic spine infections

Pyogenic spinal infection can be thought of as a spectrum of disease comprising spondylitis, discitis, spondylodiscitis, pyogenic facet arthropathy and epidural abscess.[3] Normally they are the same identity usually dominated by one or the other, and decision of surgical treatment and the technique or approach to use can be made according to the characteristics and layout of the lesion in imaging tests and other individual patient data. Urgent surgical decompression in the treatment of neurologic deficit caused by epidural abscess is the most obvious indication. Recently have been published several papers with guidelines and algorithms [4, 5] in an attempt to improve surgical indications in the treatment of spondylodiscitis. Thus, the treatment normally ends up being tailored to the patient as needed.[5] With the emergence of increasingly less invasive surgical techniques, indication of surgery can be increased for better and faster recovery for patients.

## Spinal epidural abscess

Spinal epidural abscess (SEA) has an incidence of 0.2-1.2 cases per 10,000 hospital admissions [6] and maybe this number is increasing with current estimates of incidence at more than 2 cases per 10,000 admissions while mortality is relatively stable at 5%.[7] Depending of the series the most common affected regions are lumbar [8] and/or thoracic [6] level followed by cervical. Chronic diseases and compromised immunity are associated with spinal epidural abscess and these include diabetes mellitus, intravenous drug abuse, chronic renal failure, alcoholism between others. Chronic steroid use, trauma, overaging population, and the increased prevalence of spinal implants and chronic vascular access are also risk factors.[7]

Clinically SEA produces excruciating pain over the spine with tender to percussion with or without fever, radicular o neurological symptoms for a mixed postulated mechanism with mechanical compression and vascular pathology. The source site of infection can be hematogenous spread (the most common) and include: skin infections, parenteral injections, bacterial endocarditis, urinary tract and respiratory infections and pharyngeal or dental abscess. Other sources are direct extension from other foci of infection (including penetrating trauma) and following open and closed spinal procedures.[7]

For micro-organisms involved operative cultures are the most useful procedures in identifying them. However, these cultures can be negative (moreover if the patient has been treated with antibiotics). Blood cultures are also important. In one series surgical site or interventional biopsy cultures were diagnostic in 78.8%, with concordant blood culture results in 60.0%.[8] Staphylococcus aureus is the most common organism (cultured in >50%) followed by aerobic and anaerobic streptococcus, *E. Coli*, *Pseudomona aeruginosa*, *Diplococcus pneumonia*, *Serratia marcensens* and *Enterobacter*. For chronic infections (see later) tuberculosis is the most common. Multiple organisms are cultured in ~10% and anaerobes in ~8%.[9] Leukocytosis is common in acute group, but usually normal in chronic. Erythrocyte sedimentation rate is elevated in most, usually >30.

Radiographic studies with plain films are usually normal unless there is osteomyelitis of adjacent vertebral bodies, in this case maybe is possible to see lytic lesions, demineralization and scalloping of endplates. The imaging study of choice is MRI that is able to rule out other pathologies like transverse myelitis or spinal cord infarction. In MRI there is a hypo- or iso-intense epidural mass in T1W1 (in vertebral osteomyelitis the signal is reduced in bone). In T2WI there is high intensity epidural mass that often enhances with gadolinium. This enhancement can be dense homogeneous, inhomogeneous with scattered areas of sparse or no uptake or with a thin peripheral enhancement.[10] In the acute stage enhancement can be minimal. Vertebral osteomyelitis shows up as increased signal in bone and associated discitis produces increased signal in disc and loss of intranuclear cleft.

Surgical drainage, together with systemic antibiotics, is the treatment of choice for SEAs.[7, 11] Because the preoperative neurological status is the most important predictor of final neurological outcome, surgical intervention should be performed as soon as possible.[12] Patients may be treated medically [7] in cases in which decompressive laminectomy is declined by the patient, contraindicated because of high operative risk (once more minimally invasive surgery can change this situation), unlikely to reverse paralysis that has existed for more than 24 to 36 h (although emergency decompressive laminectomy is not indicated in patients with paralysis that lasts longer than 24 to 36 hours, this surgery may still be needed to treat the epidural infection and control sepsis), or considered impractical because of panspinal infection. Patients who are neurologically intact may also qualify for nonsurgical therapy if the microbial cause is identified and the patient's clinical condition is closely monitored. Antibiotic therapy must be guided by the results of blood cultures or a CT-guided needle aspiration of the abscess. Recently has been published that SEA treated with medical management alone has a very high risk for failure if the patient is older than 65 years with diabetes, methicillin-resistant Staphylococcus aureus (MRSA) infection, or neurologic compromise. In the absence of these risk factors, nonoperative management of SEA may be considered as the initial line of treatment with close monitoring.[13] In another recent series [14] early surgery improved neurologic outcomes compared with surgical treatment delayed by a trial of medical management. More than 41% of patients treated medically failed management and required surgical decompression. Diabetes, C-reactive protein greater than 115, white blood count greater than 12.5, and bacteremia predicted failure of medical management.

*Microsurgery with tubular retractor systems*

In patients with extensive involvement of a SEA over multiple levels, the conventional surgical approach with laminectomy requires extensive exposure of the affected areas with high rates of morbidity and mortality. Drawbacks of this approach include potential compromise of spinal stability, predisposing to kyphotic deformity and instability. Further latent hazards are prolonged surgery, increased blood loss, exposure of the intraoperatively mobilized paraspinous muscles to infectious material, increased pain, delayed mobilization, and longer hospital stay and recovery time.[15-18] To avoid this is preferable using the concept of minimally invasive microsurgery via a tubular retractor system (there are various models available in market) with minimal incisions.[19] According of this technique [15] the site, extent, and upper and lower limits of infectious material collection are studied on preoperative MRI studies. The entry sites are then outlined with anteroposterior and lateral fluoroscopic images by the C-arm. If multiple separate abscesses are identified or the abscess extends over several segments, 2 or more paramedian incisions are made to insert 2 or more tubes for irrigation, evacuation, and drainage. Skin and fascia are then traversed and sequential tubular dilators of the retractor system are used to dock a ~18-mm-diameter tube (this size depends of the system used) on the lamina of the most rostral and caudal levels of the SEA. If needed, a third tube at the middle of the SEA level can be used for more adequate pus collection. In case of one smaller SEA, 1 tube may be placed at the midlevel point of the pus collection. With microsurgical technique a hemilaminectomy is completed using high-speed drilling and Kerrison rongeurs. The yellow ligament is opened subsequently to release and drain the infectious material. Once spontaneous drainage ends, small angled pituitary suction tips can be connected to Silastic tubing and placed down into the epidural space. Copious irrigation is performed until all infectious material is evacuated. Drains are not placed at the completion of the procedure. Cultures are taken during the evacuation for postoperative adjustment of the patient's antibiotic regimen. The surgeon can cautiously use straight or angled endoscopy to visualize the spinal elements and extent of evacuation as needed.

*Percutaneous endoscopic lavage and drainage.*

Another option of treatment is percutaneous endoscopic lavage and drainage (PELD). Yang *et al.*[20] treated 21 patients that had advanced lumbar infectious spondylitis. Patients with severe infection resulting in significant neurological deficit and mechanical instability were excluded from the PELD procedure, which was only used on selected patients with less severe disease. In their results causative bacteria were identified in 19 (90.5%) of 21 biopsy specimens. All patients reported satisfactory recovery and relief of back pain, except three with multilevel infections who underwent anterior debridement and fusion within 2 weeks after treatment with PELD. The overall infection control rate was 86%. One patient with epidural abscess and spondylolytic spondylolisthesis of the L5-S1 received instrumented fusion surgery due to mechanical instability 5 months later. No surgery-related major complications were found, except 2 patients who had transient paraesthesia in the affected lumbar segment. They concluded that PELD was successful in obtaining a bacteriologic diagnosis, relieving the patient's symptoms, and assisting in eradication of lumbar infectious spondylitis. Indications of this minimally invasive procedure could be extended to treat patients suffering from spinal infections with paraspinal abscesses and postoperative recurrent infection.

*Treatment of cervical epidural abscesses*

Cervical spine is an uncommon place for spondylodiscitis but is more often associated with epidural abscesses,[3] clinical presentation usually begins with severe, rapidly worsening neck pain radiated to the interscapular region and/or upper limbs and with or without fever, neurological deficits and blood test abnormalities.[21] According to Muzii *et al.*[21] a good option treatment, if there is no spinal instability (vertebral height reduction of 50% and/or spinal angulation >20°), is microsurgery via anterior approach; with a single-level discectomy with curettage of the disc plates at the level of the discitis. In case of two or more level discitis, discectomy can be performed only at the level where the abscess is thickest. Posterior longitudinal ligament has to be incised, and pus removed. A radiopaque silicone spinal catheter (diameter 1.5 mm) can be inserted into the anterior epidural space

and used to perform lavage to remove pus located cranially and caudally to the disc space. Biopsies of disc cartilage, bone, and pus are obtained for bacteriological and pathology examination. Fluoroscopy is used to ensure that the catheter reaches the limits of the abscess as shown on MR imaging. Finally, lavage of the epidural space is performed with antibiotics. A cervical collar for 8 to 16 weeks is recommendable. However it is also possible to perform an endoscopy-assisted minimally invasive microsurgery via posterior approach to treat an anterior cervical epidural abscess,[22] the decision can be made according to the characteristics and layout of the lesion in imaging tests and other individual patient data.

*Treatment of lumbo-sacral epidural abscesses*

In addition to the previously mentioned options (microsurgery with tubular retractors and PELD), another approach in the treatment of lumbosacral epidural abscesses is using the sacral hiatus and canal as a corridor for image-guided minimally invasive access to lumbosacral epidural abscess for aspiration.[23] The procedure can be done with local anesthesia and conscious sedation. The patient is placed prone on a fluoroscopy table. With a 5-french micropuncture kit is possible to access the hiatus under fluoroscopic guidance. A microwire is then advanced along the sacral canal. An 18-gauge needle curved to approximate the contours of the sacral canal is then advanced over the guidewire. Once anatomic access is established pus can be aspirated. A similar case and approach but under CT- fluoroscopic guidance has been published by Kostanian *et al*.[24] Likewise, epiduroscopy could be used for a direct visual control in this approach for this indication (author's suggestion).

## Pyogenic spondylodiscitis

Vertebral osteomyelitis is usually associated with discitis, for this reason and to simplify this review we refer to both like pyogenic spondylodiscitis. Normally they are the same identity usually dominated by one or the other. However various peculiar situations will be name and discuss. Do not forget also, as noted above, that epidural abscess may be present at once.

Vertebral osteomyelitis or pyogenic spondilodiscitis have a similar presentation and risk factors to epidural abscess. They are more common in elderly patients with urinary tract infections, diabetes and with other immunosuppresion factors. Typically are monomicrobial and *Staphylococcus aureus* is the most common organism.[25] Hematogenous spread of bacteria through the arterial paravertebral collateral vessels into the subchondral bone marrow of the vertebral bodies is the most common source of infection. Clinical presentation is often nonspecific with localized pain, fever, weight loss, paraspinal muscle spasm and radicular symptoms or myelopathy. Important diagnostic measurements are laboratory studies, radiological evaluation including MR image scans, X-ray (these are used to obtain the material by needle biopsy (Yamshidi needle) following the technique described by Valls *et al*.[26]) and CT-guided percutaneous biopsy of the lesion for microbiological studies and for rule out tumor. The management of spinal infections consists of adequate antimicrobial therapy over 6-8 weeks (in other infections like tuberculosis this time is greater). Surgical intervention usually is indicated in neurologically compromised patients for spinal instability and abscesses [27] or in patients with progression of disease despite adequate best-case therapy or chronic infection refractory to medical management. However, indication of surgery can be done for better and faster recovery for patients.

## Noncomplicated pyogenic spondylodiscitis

The treatment in noncomplicated pyogenic spondylodiscitis generally is based on intravenous antibiotics and rigid brace immobilization after an adequate clinical history, physical exam and diagnostic tests (blood tests with cultures, MRI with and without contrast) and percutaneous needle biopsy for pathology and cultures that should include fungal, aerobic anaerobic bacterial and tuberculosis.[25] Candidates for non-surgical treatment in pyogenic spontaneous spondylodiscitis have: organism identified, antibiotic sensitivity, single disc space involvement with little vertebral body involvement, minimal or no neurologic deficit and minimal or no spinal instability.[28] Maybe there are other possibilities that are discussed below.

*Percutaneous transpedicular discectomy and drainage*

Spondylodiscitis can be treated with percutaneous transpedicular discectomy and drainage.[29] Hadjipavlou *et al.* argue this technique because early debridement of these infections by percutaneous transpedicular discectomy can accelerate the natural process of healing and prevent progression to bone destruction and epidural abscess and delayed treatment may result in serious neurologic complications. This intervention can be performed under general anesthesia or with local anesthesia with conscious sedation when there is a considered high risk for general anesthesia due to septic condition or other serious medical conditions. With the patient lying prone, the operator introduces a percutaneous guide pin (2 mm Steinmann) with fluoroscopic guidance into the pedicle caudal to the affected intervertebral disc. The pin tip is centered in the pedicle on an anterior-posterior fluoroscopic view. After a lateral view of the guide pin, a cephalad angulation in the sagittal plane allows the center of the disc to be reached without violating the confinements of the pedicle to the disc. Access through a more cephalad pedicle has the potential of penetrating into the inferior borders of the pedicle and compromising the exiting nerve root. Once tip of the pin has reached the inner annulus of the posterolateral portion of the disc guide is possible to put guides and tissue dilators with a sleeve to form a corridor for working inside the disc and vertebra. To remove the disc is possible to use modified Karabin discectomy forceps and/or flexible automated nucleotome. The next step is to wash and drain by passing metal-braided sheaths through the pedicular channels using a solution of 10 mL saline and antibiotics determined by Gram's stain or culture results. This procedure would be very effective in the early stages of spondylodiscitis before the onset of extensive bone destruction or the formation of large epidural abscess or infected disc herniation. The advantage of this procedure is its minimal invasiveness that allows bacteriological and histological testing, drainage of infected material, prompt relief of pain and suffering, and early patient mobilization. Percutaneous transpedicular discectomy should also be considered as a cost-effective procedure because most patients can be discharged on the second or third postoperative day, thus decreasing prolonged hospital stay necessary for bed rest and analgesia control.[29]

*Percutaneous lumbar disc biopsy*

Percutaneous lumbar disc biopsy is a minimally invasive procedure for obtaining sufficient biopsy material for histological analysis and culture in cases of vertebral osteomyelitis.[30, 31] The rate of secondary surgical intervention may be reduced if infected disc material is removed by percutaneous biopsy. Haaker *et al.*[31] treated sixteen patients having eight of them moderate changes on computed tomograms (CT scans) and magnetic resonance MRI in the initial stages of the disease. The other eight showed more or less extensive osteolytic lesions of one or both vertebral bodies adjacent to the involved disc. The histology results showed non-specific discitis in 9 patients and tuberculosis in one. In two patients an open biopsy had been performed, which showed non-specific discitis. Microbiological analysis revealed specific infection in 45% of the patients (maybe this is a low percentage because patients had received antibiotic treatment during eight days before). These patients received a specific antibiotic treatment after antibiogram for an average of 33 days. Only three patients were treated surgically, with evacuation of the disc space and interbody fusion; the whole group received a spondylitis brace. All patients obtained satisfactory clinical results at the last follow-up regarding pain, mobility and spontaneous fusion of the involved disc space.

*Percutaneous suction aspiration and drainage*

A further step in the above process is to add suction aspiration and drainage.[32] Ando *et al.*[33] treated forty patients with pyogenic spondylitis by percutaneous suction aspiration and drainage. Surgical approach and procedure, like in the previous technique, is similar to the percutaneous discectomy for the treatment of intervertebral disc herniation.[34] With the patient positioned laterally or prone, and under local anesthesia (with or without sedation or general anesthesia if is needed) Mayer's instrument [34] with an outer diameter of 5.4 mm is inserted toward the intervertebral disc under real time fluoroscopic guidance. The entry point and angulation are determined based on CT obtain just before operation, and direction and depth are confirmed by fluoroscopy during the procedure. The affected disc is removed with forceps and the endplate of the intervertebral disc is curetted with a motor-driven shaver. After, the affected region is irrigated with a large amount

of normal saline. Then, a suction drainage tube (outer diameter 3-4 mL) and an epidural catheter are placed into the affected disc. Suction aspiration is then applied during three weeks and antibiotics administrated directly through the epidural catheter for two weeks. In thoracic cases where is difficult to enter due to presence of a rib is possible to do a transpedicular approach. When pain decreases and patient is able to stand up and walk this is allowed with a brace. The treatment is completed with systemic antibiotics. With this management Ando et al. obtained a response rate with an excellent or good outcomes in 29 patients (72.5%), with fair in five and poor response in six patients. They concluded that indications for this procedure are: 1) resistance to conservative therapy (2-3 weeks); 2) involvement of segments at or below the level of the mid and lower thoracic segments; 3) involvement of two or less segments; 4) moderate or less severe bone destruction; 5) absence or abnormal spinal arrangement requiring spinal reconstruction; 6) absence of intense motor paralysis; and 7) cases with a poor general condition. Also percutaneous discectomy and drainage have demonstrated its effectiveness in postoperative intervertebral discitis.[35] Nagata *et al.*[36] had 20 (87%) of the 23 patients with good results according to the evaluation after two years of follow-up. The causative organism was identified using tissue culturing in 12 (52%) of the 23 patients.

In cases where there is also psoas muscle abscess is possible to combine continuous irrigation using a saline infusion tube inserted into the infectious spondylitic disc as the primary lesion and insertion of a drainage tube into the iliopsoas abscess communicating with the primary lesion.[37]

### *Percutaneous endoscopic discectomy and drainage*

Similar results have Yang *et al.*[38] in a series with 15 patients treated with a similar technique and approach described above but moreover using the endoscope (percutaneous endoscopic discectomy and drainage [PEDD]) and after a drainage tube connected to a negative-pressure Hemovac. Another publication [39] compared PEDD and CT-guided biopsy for identifying the offending pathogens analyzing the diagnostic and therapeutic values of these methods. Twenty patients were treated with PEDD and the other 32 patients underwent CT-guided biopsies. In the PEDD group, causative bacteria were identified in 18 (90%) of 20 biopsy specimens, whereas in the CT-guided biopsy group, causative bacteria were identified in 15 (47%) of 32 specimens. Five patients (25%) in the PEDD group underwent anterior fusion surgery with autografting due to progressive infection or kyphotic instability. Of the 15 patients with positive culture findings in the CT-guided biopsy group, 8 (53%) underwent surgical treatment. Of the remaining 17 patients with negative biopsies, 10 (59%) patients required surgical treatment. No biopsy-related complications or side effects were observed in either group. In comparison with CT-guided biopsy, PEDD provided retrieval of greater number of specimens, yielding higher diagnostic efficacy. Therefore, the rate of secondary surgical intervention was reduced after debridement of infected tissues by PEDD, combined with prompt application of adequate antimicrobial therapy. The positive-culture rate of PEDD is comparable with those obtained with open biopsy.[40] Authors concluded that PEDD is a superior alternative to CT-guided spinal biopsy and should be considered first for treating infectious lumbar spondylodiscitis.

### *Percutaneous endoscopic debridement with dilute betadine solution irrigation*

Recently Yang *et al.*[41] have published another new series of 32 patients on causative bacteria were identified in 28 (87.5%) of 32 biopsy specimens. They used in this series percutaneous endoscopic debridement with dilute betadine solution irrigation (PEDI). The approach is done in two both sides of the same level with two working sheaths for sufficient extirpation and extensive debridement of the infected intervertebral disc and even some endplate from different endoscopic direction. After the biopsy and debridement procedures, at least 10,000 mL of dilute betadine solution is used for irrigation. Approximately 35 mL of povidone-iodine is diluted with 1000 mL normal saline to achieve a 0.35% betadine solution for use during the operation. One portal is connected to a lavage fluid pump for the inflow and the other portal is connected to a suction bottle for the outflow, with continuous infusion. The suction function is usually kept open from the beginning to the end of the procedure for further drainage of the lavage fluid and abscess. Twenty-seven (84.4%) patients reported satisfactory relief of their back pain after PEDI. Twenty-six (81.3%) patients recovered uneventfully after PEDI and sequential antibiotic therapy. No surgery-related major

complications were found, except 3 patients with transient paresthesia in the affected lumbar segment.

*Percutaneous discectomy device*

Wattamwar *et al.*[42] have used a percutaneous discectomy device (which was designed to extract disc tissue from a target intervertebral disc by using imaging guidance) to evaluate and treat 19 patients with suspected infectious spondylitis. Nineteen consecutive patients underwent imaging-guided spine biopsy with needle aspiration and with a percutaneous discectomy device to determine if the discectomy device provided diagnostic value. In 79% of cases, the discectomy device yielded a specimen when needle aspiration failed. A significantly greater yield of specimen was observed with the discectomy device, and 50% of cases with failed needle aspiration had biopsies positive for infection. The approach was similar to previously described to access the disc. The summary of the technique is as follows: an initial aspiration attempt is made by using a 20-gauge spinal needle. The 20-gauge spinal needle is exchanged over a 22-gauge removable hub needle for either a 17- or 13-gauge guide needle. An aspiration attempt is made through the 17-gauge needle. A 6-inch percutaneous device is then coaxially deployed through the guide needle. The tip of the device and its excursion could be safely monitored under imaging guidance. With the probe tip in the disc space, the device is activated, and any fluid and disc material are harvested at the probe tip and are delivered to a collection chamber. After sample collection, the device is removed. The guide needle is again exchanged over a 22-gauge removable hub needle for a 12-gauge bone biopsy needle. A bone biopsy of the vertebral endplate is also obtained with the bone biopsy needle.

*Percutaneous posterior screw-rod instrumentation*

Nasto *et al.*[43] began to offer percutaneous posterior screw-rod instrumentation as an alternative approach to rigid bracing to their patient diagnosed with single-level noncomplicated lower thoracic or lumbar noncomplicated pyogenic spondylodiscitis. Posterior instrumentation compared with standard thoracolumbosacral orthosis (TLSO) rigid bracing immobilization did not offer any advantage in healing time because infection clearance was strongly dependent on proper antibiotic therapy. Nevertheless, surgical stabilization was associated with faster recovery, lower pain scores, and improved quality of life compared with TLSO conservative treatment at 1, 3, and 6 months after treatment. For these reasons posterior percutaneous spinal instrumentation is a safe, feasible, and effective procedure in relieving pain, preventing deformity, and neurologic compromise in patients affected by noncomplicated lower thoracic (T9-T12) or lumbar pyogenic spondylodiscitis. Ha et al. have published one series [44] with 16 consecutive patients with lumbar infectious spondylitis and treated with percutaneous posterior instrumentation followed by direct lateral interbody fusion with autogenous iliac bone graft. In this last group of patients bony fusion and eradication of primary disease were obtained in all patients except 1 case during the follow-up. Preoperative VAS (7±1.2) and ODI (61.3±5.4) scores improved significantly at the last follow-up (VAS, 3.4±1.5; ODI, 32.3±15.4) and C-reactive protein normalized at postoperative 20.1±0.7 days (range, 15-28 d). Although height and lordosis in the affected segment were restored by surgery, all patients showed loss of the restored lordosis and height at the final follow-up. Loss of the restored lordosis and height were related to subsidence of the grafted bone. Similarly, Blondel *et al.*[45] had good results in their series of 10 patients with percutaneous osteosynthesis in septic conditions in association with an anterior graft in the treatment of pyogenic spondylodiscitis. Deininger *et al.*[46] obtained a large decrease in pain as well as other good clinical results in eight patients treated with minimally invasive dorsal percutaneous spondylodesis for the treatment of adult pyogenic spondylodiscitis.

## Complicated pyogenic spondylodiscitis

In cases of significant instability, deformity, and/or neurologic compromise that require urgent surgical intervention always is preferable to adapt the surgical procedure to the minor aggressiveness. Before surgery can be performed a CT or fluoroscopy guided sampling and culturing with the intention of discovering the microorganism responsible and apply the most appropriate antibiotic both systemically and locally during surgery. Blood vessels can also be altered in this case, both location and morphology due to the surrounding inflammatory tissue, and

therefore it is necessary to study their preoperative localization and discarding their possible breakage or preoperative formation of pseudoaneurysms. The main objectives of intervention will be firstly cleaning and debridement of the tissues affected by the infectious and inflammatory processes, decompression of the spinal canal, and secondly, the stabilization of the spine through the precise reconstruction of this.

*Drainage and irrigation via the surgically exposed epidural space*

Tschoeke *et al.*[47] have treated 73 patients with pyogenic spondylodiscitis and instability of the lumbar spine. The surgical strategy included a radical resection of the affected intervertebral disc and stabilization by intervertebral fusion using a titanium cage with autologous bone grafting using a posterior approach with additional pedicle screw-and-rod instrumentation. In cases where multilevel abscess formation was evident, the standard surgical procedure was complemented by drainage and irrigation of the abscess from posterior by carefully advancing a soft infant feeding tube via the surgically exposed epidural space under fluoroscopic guidance. They concluded that the onetime epidural lavage presented in their small patient cohort proved to be an effective surgical adjunct with minimal exposure-related morbidity.

*Minimally invasive thoracoscopic spine surgery*

In cases of thoracic involvement or upper lumbar levels standard surgical approach to thoracolumbar vertebral osteomyelitis requiring extensive thoracotomy or retroperitoneal exposure carries significant associated morbidity and postoperative pain. Minimally invasive thoracoscopic spine surgery [48, 49] can improve postoperative morbidity associated with the traditional open surgery and thus patients undergo minimally invasive thoracoscopic radical debridement, decompression of the spinal canal and anterior spinal reconstruction and fusion. For this technique patient is in decubitus lateral position and selective lung intubation is required. Placement of the trocars with reference to the planned operation and the surgical target area is of fundamental importance for the entire course of the operation. The working portal is situated directly above the lesion and the portal for the endoscope is placed over the spine two intercostal spaces away from the working portal in a cranial direction (if lesion is in upper thoracic spine maybe can be in a caudal position). The portals for the retractor and the suction/irrigation instrument are situated ventrally from this point. The pannus or inflammatory tissue and increased vascularity of adhesions result in greater difficulty in orientation and in surgical technique, thus is very important to use as soon as possible the guide wires under fluoroscopic control.

*Mini-open anterior lumbar surgery*

For infections and other diseases in anterior lumbar spine one option of surgical treatment is mini-open anterior lumbar surgery.[50] With this approach is possible to perform anterior decompression such as anterior corpectomy or anterior discectomy, anterior bone grafting, anterior spinal fusion such as ALIF and anterior instrumentation with screws and one rod system directly. The patient is put in the lateral decubitus position and a transverse skin incision is usually made just above to the target vertebrae, and in the region between the anterior and middle axillary lines. When the target vertebra is at the T12 rib level, the incision is made one level below. If the target involved two levels (with one disc), a 4 cm incision is adequate. If the target involved three levels (two discs), the incision is extended to 6-8 cm. For the latter, complete corpectomy of the middle vertebra could be performed smoothly. A headlight or Vario retractor with lamps is used to light up the small operation field. If the lesion is in L2 to L5, muscle splitting, layer-by-layer, from external oblique abdominal muscle, internal oblique abdominal muscle, to transverse abdominal fascia is the method of choice. From T12 to L2 the anatomy in this area is widely varied. Incision could be made below the 12$^{th}$ rib, between the 11$^{th}$ and 12$^{th}$ ribs or even up to the 9$^{th}$ or 10$^{th}$ rib. Due to anatomical variations, not all muscle layers are visible during each operation. Basically, the *latissimus dorsi* and external oblique abdominal muscle are at the same level and continuously interdigitated. The diaphragm and transverse abdominal muscle are also interdigitated and at the same muscular level. Severance of muscle layers is the rule to avoid injury to intercostal or subcostal nerves. Sometimes, 2-3 cm had to be cut from the free ends of the 11$^{th}$ or 12$^{th}$ rib. In this way, chest cavity is rarely opened, once the pleura is opened,

it is easily sutured and sealed off securely. The mini-open anterior lumbar surgery technique is a retroperitoneal extrapleural approach. If the target is T12 or L1, the crus of the diaphragm must be dissected longitudinally to expose their vertebral bodies. It is possible to reach the lower part of the T12 vertebra without opening the diaphragm.

Anterior approaches with debridement/partial vertebrectomy plus mesh cage filled with autologous bone graft (open or with MIS) can be supplemented with pedicle screw fixation with minimally invasive techniques.[51]

## Tuberculosis and minimally invasive spine surgery

Spinal tuberculosis (and the same for other mycobacterial and/or granulomatous, chronic infections) is a serious disease that is highly prevalent in certain geographical areas. In many cases it is necessary to combine medical treatment (that is the cornerstone of the treatment, with a combination of various drugs, that depends of microbiological tests that patient has to take for months) with appropriate surgical treatment. Typically more subacute or chronic than pyogenic spondylodiscitis, usually affects more than one level predominantly at lower thoracic and upper lumbar levels. Vertebral body usually is the most affected part of the vertebra sparing the posterior elements. Psoas abscess is common.

Similarly to pyogenic spondylodiscitis, surgery is indicated by neurological complications, medical treatment failure, progression of lesions in spite of medical treatment, prevention of severe kyphosis in patients with extensive back injuries, spinal instability and/or the need for diagnostic confirmation. Surgical treatment may contemplate debridement and drainage of abscess, decompression, fusion and stabilization of the spine. Minimally invasive spine surgery can be a good option in the treatment. Any technique described above may be used if the characteristics of injuries to treat are propitious. Lü *et al.*[52] have treated 50 patients with anterior debridement and reconstruction via a thoracoscopy-assisted mini-open approach for the surgical treatment of thoracic spinal tuberculosis. There was statistically difference in VAS 3 months after surgery compared to preoperatively (P<0.001), as well as final follow-up compared to 3 months post-op (P<0.001). Neurological improvement of one to three grades in 26 patients by final follow-up. There was statistically difference in kyphotic angle 3 months after surgery compared to preoperatively (P<0.05), as well as final follow-up compared to 3 months post-op (P<0.001). The average correction rate of kyphotic angle was 38.7% and the loss of correction rate was 1.3% at final follow-up. No recurrent tuberculosis was found. Zhang *et al.*[53] have used CT-guided percutaneous puncture and local chemotherapy for tuberculosis of the lumbar or lumbosacral spine in 49 patients. All cases recovered, and there was no recurrence. Preoperatively, the kyphotic angle was 16.47±8.74°, and it had decreased to 13.35°± 8.02° by the final follow-up (t=5.79, P<0.001). The average ODI score had improved from 70.12±22.24 to 12.72±8.62 (t=21.42, P<0.001).

Ito *et al.*[54] have used posterolateral endoscopic debridement and irrigation followed by retention of a drainage tube at the affected sites in 3 patients with tuberculous spondylodiscitis. Also they conducted puncture and drainage at the same time when extensive cold abscesses were identified around the paravertebral muscle. All patients experienced immediate pain relief postoperatively. They concluded that this technique is effective for rapid pain relief and in obtaining neurological resolution for patients in the early stages of tuberculous spondylodiscitis and may also be a good method for preventing further vertebral collapse and kyphotic spinal deformity. Minimally invasive posterior paramedian approaches with tubular retractors with possibility of discectomy, drainage of the abscesses and percutaneous transpedicular fixation can be an option too.[55]

## Infections after minimally invasive spine surgery

It has been demonstrated that minimally invasive spine surgery improves and decreases the range of postoperative surgical site infection (SSI) compared with open surgery [56] although other studies have seen no difference.[57] In a review Parker *et al.*[58] compared post-operative infection after minimally invasive *vs.* open transforaminal lumbar interbody fusion (TLIF). They obtained a significantly lower cumulative incidence of reported surgical site infection for MIS vs. open-TLIF (0.6% *vs.* 4.0%, P=0.0005) in addition to economic impacts associated with savings in hospital costs.

Another interesting paper has analyzed the rates of infection after spine surgery based on 108,419

procedures.[59] Compared with a traditional open approach, use of a minimally invasive approach was associated with a lower rate of infection for lumbar discectomy (0.4% *vs.* 1.1%; P<0.001) and for transforaminal lumbar interbody fusion (1.3% *vs.* 2.9%; P=0.005). Other factors associated with increased rate of infection were: included revision surgery (P<0.001), performance of spinal fusion (P<0.001), and use of implants (P<0.001). O'Toole *et al.*[60] performed 1338 minimally invasive spinal surgeries in 1274 patients with three postoperative surgical site infections detected, 2 were superficial and 1 deep. The procedural rate of SSI for simple decompression was 0.10%, and for minimally invasive fusion/fixation was 0.74%. The total SSI rate for the entire group was only 0.22%. In another multihospital study [61] with 5170 patients the minimally invasive technique was associated with a decreased incidence of perioperative SSI and a direct cost savings of $38,400 per 100 P/TLIF procedure when used in 2-level fusion but there was no significant difference in the incidence of SSIs between the open and MI cohorts for 1-level fusion procedures.

Any spine percutaneous procedure or minimally invasive spine surgery has a risk of infection that can be life-threatening or with severe consequences for patients.[62-64] Abdelrahman *et al.*[65] have reported six cases with postoperative infection (0.46%) from 1307 patients that underwent percutaneous vertebroplasty or kyphoplasty. They treated also three additional cases referred from other institutions. All patients were treated surgically except one case who died before the planned revision surgery. In all cases, debridement and corpectomy were done through anterior approaches combined with posterior instrumentation. The most common causative organism was *Staphylococcus aureus* in three cases. Perioperatively mortality rate was of 33.3%. At the end of follow-up, two patients had unrestricted activities and one patient required a walker. Of three paraparetic patients, two improved functionally and could walk unassisted and one improved but still used a wheelchair. They concluded that although vertebroplasty and kyphoplasty are minimally invasive interventions, postoperative infection can develop into life-threatening complications and this should be accounted for, in decision making in the elderly age group most commonly affected by osteoporotic fractures and especially in suspicious and high-risk immune-compromised patients.

As in the primary spine infections, postoperative spine infections of surgical site (from opened classic or MIS) can be treated by minimally invasive techniques. Many infections will required an opening of the surgical wound but maybe others can benefit from MIS.[35]

## Conclusions

Using of techniques in minimally invasive surgery in spine infections is safe, effective and has benefits in morbidity of the approach and subsequent patient recovery. Today there are a lot of possibilities inside minimally invasive spine surgery like percutaneous image-guided techniques, endoscopic and microsurgical techniques with or without use of tubular retractors. All this armamentarium allows to the spine surgeon to choose the best option case by case depending of extension, location and type of infection.

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