Infections in the spine can lead to a wide range of problems for both the patient and physician. There is perhaps no more devastating complication than the neurological consequences of a cauda equina syndrome due to spinal infection. A variety of organisms and origins can cause diagnostic and treatment of spinal infection a difficult task. Both pyogenic and nonpyogenic organisms can cause vertebral involvement and can result in an epidural abscess with neurological compromise. Nonetheless, these two types of infections vary greatly in terms of associated patient demographics, clinical course, and treatments. The purpose of this paper was to review these types of infections and summarize treatment recommendations for this difficult condition.

**KEY WORDS** • cauda equina syndrome • infection • epidural abscess • tuberculosis

Neurological deficits ranging from paraplegia to paraparesis are present in 70 to 80% of patients. The reported incidence of fever varies greatly in the literature, ranging from 35 to 70%. Approximately one third of patients will present with loss of bowel or bladder function.

**Diagnostic Evaluation**

Typically, laboratory studies can be helpful in confirming the diagnosis of a spinal epidural abscess, but results of such tests are usually nonspecific. An elevated peripheral white blood cell count is present in 50 to 60% of patients, whereas an ESR and/or C-reactive protein level is present in more than 90%. Both ESR and C-reactive protein level are typically elevated following any spinal procedure (including lumbar puncture). Thus, although they can be useful markers of the effectiveness of treatment of a spinal epidural abscess, their diagnostic value is limited.

Obtaining tissue for culture and peripheral blood cultures prior to instituting antibiotic therapy is optimal. Peripheral blood cultures can demonstrate the offending organism 50 to 70% of the time, whereas direct tissue cultures demonstrate yields of 90%. Neuroimaging Studies

Plain radiographs of the spine are the easiest imaging studies to obtain, but will typically remain normal for 2 to 3 weeks after the onset of infection. Initial radiographic findings, which include loss of disc space height, loss of soft tissue planes, and subchondral endplate haziness lag behind the patient’s clinical course. Radionuclide imaging can often demonstrate changes prior to radiography. Indium-111, 67Ga, and 99Tc scans all play a role in the diagnosis of an osteomyelitis associated with an epidural abscess, but are not specific for the presence of a spinal epidural abscess.
Given the need to obtain accurate images of both soft and osseous tissues in the context of a spinal infection, MR imaging has become the modality of choice in evaluating spinal infections. In the presence of an infection, T2-weighted signal intensity will increase due to the associated edema, whereas T1-weighted signal intensity will decrease due to replacement of the marrow fat.\textsuperscript{1,2} Gadolinium enhancement can help differentiate infection from postsurgical change and pus from granulation tissue.\textsuperscript{1,26,29,32} This combination allows MR imaging studies to be 95% accurate in the diagnosis of spinal infections and epidural abscesses (Fig. 1).\textsuperscript{1,26,29,32} Sagittal MR images of the entire spine are recommended to identify the span of the abscess and possible skip lesions. Because of its accuracy, MR imaging has supplanted CT scanning as the modality of choice in detecting spinal infections and epidural abscesses. Nonetheless, CT scanning still plays an important role in guiding a biopsy as well as in assessing the degree of bone destruction.

**Microbiological Characteristics**

*Staphylococcus aureus* remains the most common pathogen in pyogenic spinal epidural abscesses, occurring in between 25 and 60% of patients.\textsuperscript{7,18,27,31} During the past decade, however, antibiotic-resistant organisms as well as an increase in intravenous drug abuse have revealed many new pathogens. Methicillin-resistant *S. aureus* now accounts for between 15 and 20% of pathogens in spinal epidural abscess, with gram-negative pathogens such as *Pseudomonas* and *Escherichia coli* becoming more common as well.\textsuperscript{31}

**Methods of Treatment**

The mainstay of treatment for pyogenic spinal epidural abscess is surgical decompression of the thecal sac with drainage of the abscess and long-term antibiotic therapy.\textsuperscript{7,18,30} The surgical approach for decompression should be modified based on particular characteristics of the case including the location of the infection (anterior compared with posterior), the region of the spine involved (cervical, thoracic, or lumbar), the presence of a significant bone or paraspinal abscess, and the degree of bone destruction revealed on CT scanning.

Many cervical abscesses are treated using anterior decompression with corpectomy and fusion with an autograft.\textsuperscript{31} In the thoracic spine the approach can vary depending on the location of compression, but generally a posterior decompression of an isolated epidural abscess can be accomplished by performing a laminectomy. The use of a costotransversectomy can facilitate a moderate degree of anterior decompression through the same incision.\textsuperscript{7,10} In the lumbar spine posterior decompression is often adequate, unless there is a large abscess in the anterior spine as well. Either a transforaminal or an anterior approach can be used to drain the abscess, but a more adequate debridement can be achieved through an anterior procedure.\textsuperscript{7,10}

If there is a significant amount of anterior bone destruction or a significant paraspinal/bone abscess, then formal anterior spinal debridement is recommended. Through various thoracotomies, any level of the thoracic spine from T-2 to T-11 can be adequately accessed. From the level of T11–L1, a 10th rib thoracotomy can be extended into a transthoracic transdiaphragmatic retroperitoneal approach to access the spine. The lumbar spine from L-2 to the sacrum can be easily accessed via a standard retroperitoneal approach. Although significant focal scarring and inflammation near the locus of infection can make these approaches technically challenging, excellent exposure can normally be achieved.

Once exposure is achieved, the infection should be widely debrided by excision of infected and necrotic bone, disc, and paraspinal tissues. The thecal sac is normally de-
Infectious origins of cauda equina syndrome

...compressed on debridement. Reconstruction of the local defect with the aid of a structural autologous bone graft is then performed. Spinal position is then maintained through bracing, or a second-stage posterior spinal stabilization procedure is performed either on the same day or at a later date. Appropriate antibiotic therapy is then continued for 6 weeks or longer to eradicate infection.

Nonsurgical methods that include percutaneous biopsy of the abscess followed by intravenous antibiotic therapy can play a role in the management of spinal epidural abscess; however, these methods should only be undertaken in very limited instances. Some authors have asserted that patients with complete paraplegia lasting longer than 48 to 72 hours can be treated nonsurgically because they have little chance of neurological recovery.30,31 Patients with pan-spinal involvement as well as those medically unable to undergo surgery can also be treated nonsurgically.31,35 The most controversial group to treat nonsurgically consists of those patients with a lumbosacral epidural abscess and a nondiagnostic neurological examination. Some authors indicate that appropriate culture methods, intravenous antibiotic agents, and careful monitoring of the neurological factors can be an acceptable treatment regimen in this group.22,23,35,39 Any decline in the patient’s neurological condition, however, mandates the need for rapid surgical intervention.4,7,15,25,38

Patient Outcomes

Patient outcome following treatment of a spinal epidural abscess varies depending on a number of factors. Those with multiple medical conditions or a history of spinal surgery appear to have worse outcomes.19,31,35 Some authors assert that patients with methicillin-resistant S. aureus infections also have worse outcomes,30 but this may be due to a delay in obtaining appropriate antibiotic coverage for the infection. Patients with thoracic infections demonstrate worse outcomes than those with infections at either cervical or lumbar sites,30,31 perhaps because of the vascular watershed area of the spinal cord in the thoracic spine. Both the degree of neurological dysfunction and the duration of time between the onset of symptoms and surgical treatment can affect patient outcomes. In one series 45% of those presenting with paraparesis regained ambulatory status, and every patient who presented with ambulatory status was able to maintain it.31 Furthermore, these authors indicated that in patients who present with paraparesis, treatment administered within 24 hours can result in better outcomes, with up to 90% of patients regaining some neurological function and 45% becoming ambulatory compared with 45% regaining no function when treatment was delayed for more than 24 hours.

NONPYOGENIC EPIDURAL ABSCESS

Patient Demographics

Although most spinal infections in the technologically developed regions are the result of pyogenic organisms, in areas that are less technologically developed and in the immunocompromised population, nonpyogenic organisms are responsible for most epidural abscesses. In the inner cities of the US among both recent immigrants and the immunodeficient population, granulomatous infections are on the rise.

Infection with Mycobacterium tuberculosis is relatively uncommon in most of the technologically developed nations; however, it is estimated that more than 1.7 billion people worldwide have been infected during their lifetime.17,24 Although most primary cases of tuberculosis are pulmonary in nature, during reactivation of the disease, musculoskeletal involvement can frequently occur. This results in approximately 10% of all patients with tuberculosis demonstrating musculoskeletal involvement together with Pott disease (tuberculous spondylodiscitis) and accounts for half of all musculoskeletal cases.

Clinical Presentation

Rather than experiencing an acute onset of symptoms, patients with Pott disease typically have a more insidious onset of symptoms, especially compared with patients suffering from pyogenic infections. Back pain is an almost universal symptom in patients with spinal tuberculosis,16,21,24 but neurological signs vary widely, although 10 to 80% of patients present with deficits.16,21,24 Fever is not typical even though it occurs in approximately 30 to 50% of patients.16,21,24 Other constitutional symptoms such as malaise and weight loss are far more common as a result of the chronic nature and insidious progression of the disease.16,17,21,24 These disease characteristics can often lead to significant deformity at the time of diagnosis, which is uncommon in pyogenic infections.

Diagnostic Evaluation

As in cases of pyogenic infections, laboratory studies can be helpful in confirming a diagnosis of nonpyogenic infection, but results are frequently inconclusive. An elevated peripheral white blood cell count does not typically occur in spinal tuberculosis. In contrast, the chronic nature of the disease or an associated immunosuppressed state will often cause a lower than normal count. Typically, the ESR is moderately elevated.16,17,21,24 A purified protein derivative test is often positive, but can result in a false-negative finding in a chronically debilitated or immunosuppressed patient.17 Sputum cultures and acid-fast staining may be helpful if active pulmonary disease is present, but require many weeks to grow. Definitive diagnosis is usually made based on CT-guided biopsy and cultures of the lesion, but again this can require long periods for culture growth. More recently, subjecting the biopsy specimen to a polymerase chain reaction study has been shown to be more than 93% accurate in making a diagnosis and can help detect drug-resistant strains before initiating antibiotic therapy.17

Radiological Imaging

Unlike pyogenic infections, plain radiographs will often demonstrate many bone changes due to the insidious nature of the nonpyogenic infection. A varying degree of deformity from bone erosion is typically seen at the time of patient presentation.21 Nuclear imaging modalities are less useful and reliable than in pyogenic infections, with false-negative rates approaching 40 and 70% for 99mTc and 67Ga scans, respectively.17
Magnetic resonance imaging remains the best single modality for the evaluation of extent of disease and the detection of epidural compression and granulomas. Gadolinium enhancement will often allow for differentiation of abscess and granulomas.\textsuperscript{5,16} In nonpyogenic infections, the disc spaces are relatively resistant to invasion compared with disc spaces in pyogenic disease. This will often result in an image of multiple-level vertebral involvement, with relative sparing of the discs (Fig. 2).

**Microbiological Characteristics**

In less technologically developed nations, tuberculosis is endemic and \textit{M. tuberculosis} accounts for the majority of all organisms causing nonpyogenic epidural abscesses.\textsuperscript{24,34} In technologically developed countries, tuberculosis is not generally endemic, but \textit{M. tuberculosis} still causes most of the nonpyogenic infections that occur. Note, however, that other mycobacteria, fungi, and spirochetes cause granulomatous infections in the immunocompromised populations. \textit{Mycobacteriaceae}, \textit{Actinomycetaeae}, \textit{Nocardia spp.}, \textit{Candida spp.}, and \textit{Aspergillus spp.} have all been seen as pathogens in nonpyogenic spinal infections and epidural abscesses.\textsuperscript{5,6}

**Treatment Methods**

Nonpyogenic epidural abscesses are amenable to both nonsurgical and surgical management, depending on the individual case. In general, the goals of treatment of tuberculous epidural infections include disease eradication, pain relief, preservation of neurological function, and spinal stability.\textsuperscript{24,34} Because most patients with these infections are debilitated due to the chronic nature of the disease, nonsurgical management is often preferred. Thus, indications for surgical care are limited and include failure to obtain diagnostic tissue by other means, presence of a progressive neurological deficit (unless it is complete paraplegia lasting > 3 days), severe spinal instability and deformity, or failure of medical management to control disease.\textsuperscript{24,34}

**Nonsurgical Management.** The nonsurgical management of nonpyogenic epidural abscesses can be stated in three simple concepts: nutritional support, spinal immobilization, and appropriate antibiotic therapy. Due to the chronic and often indolent nature of these infections, most patients present with protein-calorie malnutrition. This type of malnutrition causes impaired cell-mediated immunity, and impaired pulmonary immune defenses can have a direct impact on the success of any therapy. Thus, nutritional supplementation must be a priority in these cases.\textsuperscript{17} Spinal immobilization through either bedrest or orthosis to control pain and deformity is the standard of care. Orthoses ranging from halo vests to cervicothoracolumbar devices may be needed, depending on the location and extent of spinal involvement. A minimum of 3 months of brace therapy is required, but the degree of deformity and osseous destruction and the disease response may lengthen the period of this treatment.\textsuperscript{21,24,34} Antibiotic therapy should be initiated once it is confirmed that diagnostic tissue has been obtained. Triple antibiotic therapy involving a 12-month administration of isoniazid, rifampin, and pyrazinamide is standard, but the regimen may need to be modified if there is a failure to respond or if drug resistance is present, which can be determined based on polymerase chain reaction testing.\textsuperscript{24,34} For nontuberculous organisms, different drug regimens are needed; hence, it is paramount to have an infectious disease specialist control the antibiotic care.

**Surgical Management.** The surgical management of nonpyogenic epidural infection is normally limited to cases of unstable deformity or progressive neurological defi-

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**Fig. 2.** \textit{Left:} Sagittal T\textsubscript{1}-weighted MR image obtained in a patient with lumbar kyphosis and reactivation of Pott disease. Note the primary involvement of multiple vertebral bodies. \textit{Center:} Sagittal T\textsubscript{2}-weighted MR image exhibiting relative sparing of disc spaces and epidural compression. \textit{Right:} Sagittal T\textsubscript{1}-weighted Gd-enhanced image displaying relative sparing of disc spaces and epidural involvement.
decline in neurological function mandates surgical inter-
ecessitates, medical management can be initiated, but any sign of 
patients with pyogenic abscesses without neurological def-
ations can result in devastating outcomes in patients. Based 
on the nature of the infection (pyogenic compared with nonpyogenic) and the duration of symptomatology, either surgical or nonsurgical care can play a pivotal role in the long-term outcome in a patient. In general, recently progressive neurological deficits (that is, those occurring within 48 hours) require surgical intervention in almost all patients regardless of the nature of the infection. In patients with pyogenic abscesses without neurological deficits, medical management can be initiated, but any sign of decline in neurological function mandates surgical intervention.

CONCLUSIONS

Cauda equina syndrome associated with spinal infections can result in devastating outcomes in patients. Based on the nature of the infection (pyogenic compared with nonpyogenic) and the duration of symptomatology, either surgical or nonsurgical care can play a pivotal role in the long-term outcome in a patient. In general, recently progressive neurological deficits (that is, those occurring within 48 hours) require surgical intervention in almost all patients regardless of the nature of the infection. In patients with pyogenic abscesses without neurological deficits, medical management can be initiated, but any sign of decline in neurological function mandates surgical intervention.

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Patient Outcomes

The result of treating of nonpyogenic epidural infec-
tions can be quite remarkable. With nonsurgical manage-
ment, if the spinal deformity can be controlled with brace therapy, most areas of destruction will undergo some de-
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Address reprint requests to: David B. Cohen, M.D., M.P.H., Department of Orthopaedic Surgery, Johns Hopkins University, 601 North Caroline Street, Baltimore, Maryland 21287. email: dcohen@jhmi.edu.