Thoracic Epidural Abscesses: A Systematic Review

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Abstract

Study Design: Systematic review.

Objectives: Past research has demonstrated increased speed and severity of progression for spinal epidural abscesses (SEAs) of the thoracic level, specifically, when compared with SEAs of other spinal cord levels. Untreated, this infection can result in permanent neurological sequelae with eventual progression to death if inadequately managed. Despite the seriousness of this disease, no articles have focused on the presentation, diagnosis, and treatment of SEAs of the thoracic level. For this reason, specific focus on SEAs of the thoracic level occurred when researchers designed and implemented the following systematic review.

Methods: A query of Ovid-Medline and EMBASE, Cochrane Central, and additional review sources was conducted. Search criteria focused on articles specific to thoracic epidural abscesses.

Results: Twenty-five articles met inclusion criteria. The most commonly reported symptoms present on admission included back pain, paraparesis/paraplegia, fever, and loss of bowel/bladder control. Significant risk factors included diabetes, intravenous drug use, and advanced age ($P = .001$). Patients were most often treated surgically with either laminectomy, hemilaminectomy, or radical decompression with debridement. Patients who presented with neurological deficits and had delayed surgical intervention following a failed antibiotic course tended to do worse compared with their immediate surgical management counterparts ($P < .005$).

Conclusions: For the first time researchers have focused specifically on SEAs of the thoracic level, as opposed to previously published general analysis of SEAs as a whole. Based on the results, investigators recommend early magnetic resonance imaging of the spine, laboratory workup (sedimentation rate/C-reactive protein, complete blood count), abscess culture followed by empiric antibiotics, and immediate surgical decompression when neurological deficits are present.

Keywords

thoracic epidural abscess, epidural abscess, spine abscess, SEA, EDA, systematic review

Introduction

Spinal epidural abscess (SEA) is a potentially life-threatening medical emergency that often warrants immediate medical (antibiotic) and/or surgical intervention.[1] SEAs develop through either direct spread from a contiguous site (vertebral osteomyelitis, overlying cellulitis, epidural injection)[2] or via hematogeneous seeding of the epidural space often seen in intravenous drug users, septic patients, or patients with generalized bacteremia.[3,4] SEAs can progress rapidly and have the potential to cause irreversible neurological deficits when treatment is delayed.[5-8] A recent study conducted by the

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Department of Veterans Affairs found that 55% (n = 66) of all SEA cases were initially misdiagnosed. Time to correct diagnosis was 12 days in patients initially misdiagnosed, versus 4 days for patients properly diagnosed ($P < .01$).[9] Misdiagnosis in this study was most often the result of inadequate recognition of "red flag" signs (unexplained fever, progressive neurological deficits, active infection) and inadequate initial evaluation as performed by the treating physician (n = 60; 90.1%).

Prior research on clinical manifestations and disease progression of SEAs found significant differences across spinal cord regions (cervical vs thoracic vs lumbar).[10-13] Khanna et al previously described more rapid and severe onset of neurological deficit in patients with cervical and thoracic SEAs relative to patients with lumbar SEA.[14] One possible explanation of this finding is that the smaller canal diameters in the thoracic spinal cord lead to more severe early compression of the spinal cord in the thoracic spine compared with the lumbar spine. In support of this theory, several studies have previously reported patients with SEAs of the thoracic spine presented more abruptly and with more severe neurological deficits when compared with similar patients with SEAs located in more caudal spinal cord levels.[15-17]

Logical organization of information surrounding thoracic SEAs from a spine surgeon's perspective would ideally include the following components: (1) patient symptomology (typical signs and symptoms); (2) the clinical approach and diagnostic workup; (3) treatment failure and risk factors for failure of medical management (pharmacotherapy alone); (4) neurological recovery rates and effect of medical management versus surgical treatment, specifically, in relation to time to treatment; and (5) Indications for stabilization in patients presenting with thoracic SEAs. With this in mind, investigators are limited by the existing body of evidence as it relates to thoracic SEAs rather than SEAs of all spinal cord levels in general. Organization of information extracted depends heavily on the current research landscape.

Despite prior research indicating that thoracic SEAs expand and compress important spinal cord structures earlier than SEAs at other levels, there is a gap in the literature about optimal management of thoracic SEAs. For this reason, the present study focused on synthesizing the available evidence regarding clinical manifestations, natural history, and management of thoracic SEAs with the aim of reducing morbidity and mortality associated with misdiagnosis or delayed treatment.[9,14]

Methods

Search Strategy

Investigators conducted a search review of 3 databases—Medline, Embase, and Cochrane Central—with the following search term strategy: ("Epidural Abscess" OR "SEA") AND ("Thoracic" OR "Thoracic Vertebrae"). Subsequent review of other literature sources (Google Scholar, PubMed) employed a similar search strategy (key terms: "Epidural Abscess" or "SEA" AND "Thoracic" OR "Thoracic

Vertebrae"). In total, 693 articles were identified from the database and outside source search (Figure 1). The search period ended June 28, 2017.

Inclusion and Exclusion Criteria

Articles were included if they reported results relating to epidural abscess of the thoracic spine. Retrospective cohort studies, prospective cohort studies, and clinical trials were the only study types included due to their superior quality of evidence when compared with case reports or expert advice.[18] Case reports were excluded from the current study.

Articles that did not stratify results by spinal cord region (cervical, thoracic, or lumbosacral) and articles that focused on spondylitis or spondylodiscitis or infection of the spinal cord in general without focus on epidural abscess of the thoracic spine were excluded.

Data Collection

Two trained reviewers (BH and ID) independently reviewed each study at each of the 4 stages described below. At each of the 4 stages, a third author (JT) acted as final arbiter when inclusion and exclusion disagreements arose. First, duplicates from the 693 articles were deleted and the remaining article titles were screened for inclusion. Second, among those studies that were included following the title review, full abstracts were read and inclusion and exclusion criteria were again reviewed. Third, after studies were included following abstract review, the full manuscript was reviewed and a final decision of inclusion or exclusion was made. Data extraction of the final sample of articles involved independent review of each article by 2 trained reviewers (BH and ID). Included articles were assessed for level of evidence based on the Oxford Center for Evidence Based Medicine (OCEBM) evaluation criteria.[19]

Results

Of the 693 articles obtained from the initial search, 480 remained after 213 duplicates were removed. An additional 452 articles were removed following the initial title review, and the resultant 27 remaining articles were screened based on abstract content alone. After this review, 2 additional articles were excluded following independent review of the full text content. In total, 25 articles (see the appendix) were included in the final analysis based on the aforementioned data collection methodology (Figure 1). Of the 25 articles, 24 articles were retrospective reviews and 1 was a prospective cohort. Articles were published between 1990 and 2017. Based on recurring themes found throughout included articles, our findings were separated into 5 categories: (1) clinical presentation, duration of symptoms, and risk factors; (2) radiological, microbiology, and laboratory findings; (3) pharmacological management; (4) surgical management; and (5) patient outcomes.
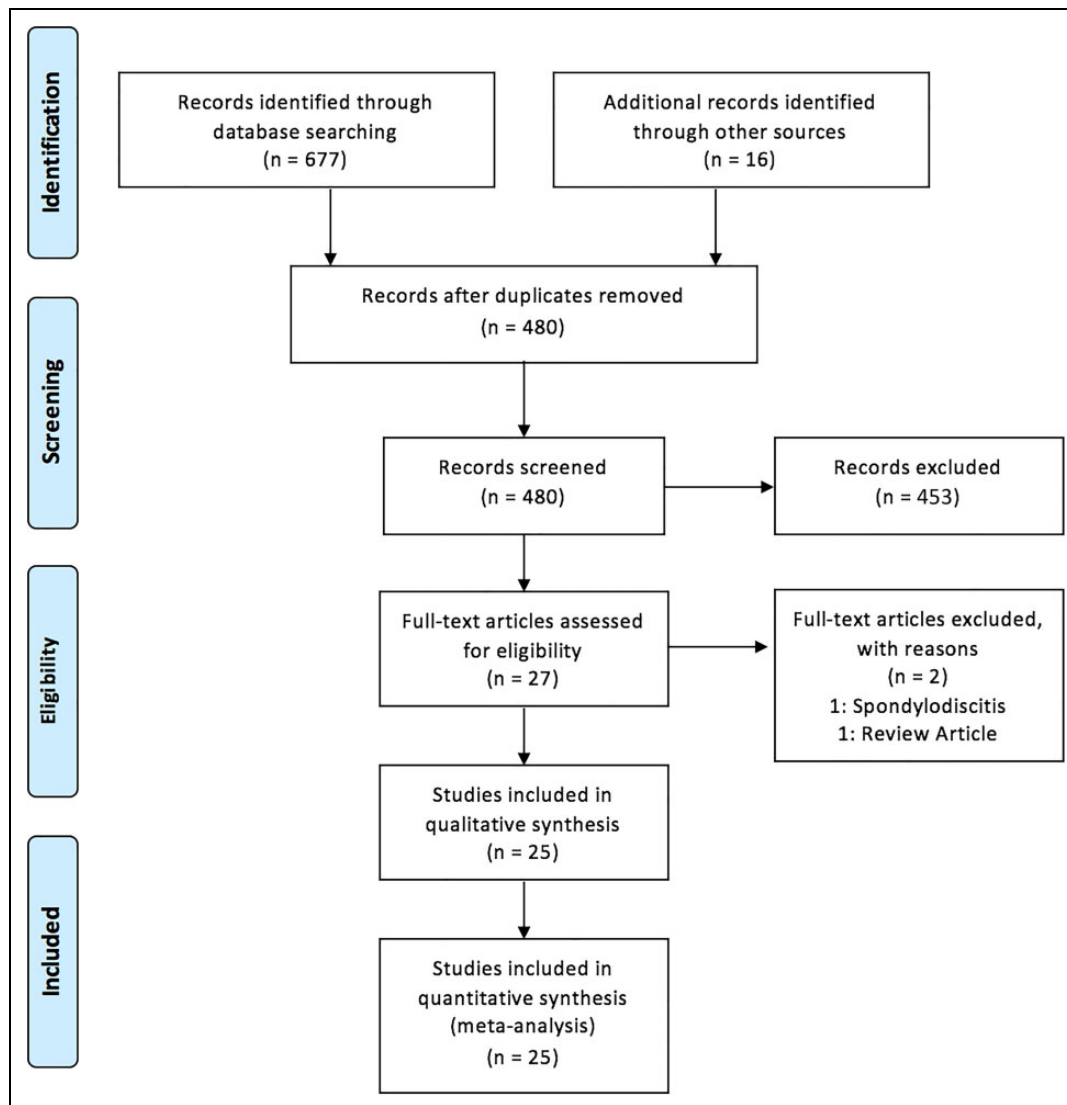
Figure 1. Thoracic SEA systematic review PRISMA flow chart.

Clinical Presentation, Duration of Symptoms, and Risk Factors

Of the 25 included articles, 22 (88%) provided case information on presenting symptoms, clinical progression, and risk factors associated with development of thoracic SEA prior to hospital admission (Table 1). Back pain (n = 16; 64%),[3,12,20-33] neurological deficits (n = 17; 68%),[3,12,20-30,32-35] including paraparesis (n = 12; 48%)[3,20,22,24,26,28-30,33-36] and paraplegia (n = 5; 20%),[22,24,28,34,35] fever (n = 6; 24%),[3,21,23,24,26,29] and loss of bowel or bladder control (n = 4; 16%)[22,25,26,34] were among the most commonly reported symptoms present at time of admission.

Clinical progression and time to admission following onset of symptoms was variable, but largely underreported by investigators. Of the 3 studies that did report clinical progression from onset of symptoms to follow-up after surgery, 2 studies documented the presence of pain occurring first followed by progression to concomitant pain with neurological deficits

(8%).[25,35] Hadjipavlou et al noted that back pain generally preceded the onset of neurological deficits.[35] Kuker et al reported a similar pattern of preceding back pain prior to the onset of neurological deficits in patients diagnosed with thoracic SAE. However, in their study the lag between pain and neurological symptoms was highly variable (median: 2.7 months).[25] According to Boström et al, patients waited between 12 hours to several months from time of symptom onset (back pain, weakness, neurological dysfunction) to present for medical treatment of thoracic epidural abscess.[32]

Risk factors for developing thoracic SEA can be divided into either modifiable or nonmodifiable risk factors. Among the modifiable risk factors, alcoholism and intravenous drug use were most strongly associated with thoracic SEAs.[3,12,21,32] Bacteremia caused by nonsterile injection needles was the most commonly identified preventable risk factor (n = 3; 12%). However, thoracic SEA has been observed after lumbar epidural steroid injections as well.[37]

Table 1. Clinical Presentation and Duration of Symptoms.

Author (Year Published)	Presenting Symptoms	Duration of Symptoms Prior to Admission	Risk Factors
Abdelrahman et al (2017)	Neurological deficit (ASIA A-D) present in 51.2%	—	Overall recovery for patients with paraparesis/paraplegia after epidural abscess was 20% for all levels. No patients with paraparesis/paraplegia from thoracic abscess recovered versus 50% recovery in lumbar epidural abscess. Incidence increase with age ($P = .001$): 54.5% older than 60 ($P = .003$); 57.4% over 80 years old due to immunosuppression and immunocompromised.
Aryan et al (2007)	Both presented with myelopathy	—	—
Boström et al (2008)	Frankel A in 5; B in 3; C in 6; E in 3; back pain present in all	12 hours to several months	Diabetes mellitus (n = 4), alcoholism (n = 4), immunosuppression (n = 4), malignancy (n = 3), peridural catheter (n = 3), intravenous (IV) drug abuse (n = 2), previous spinal operation (n = 2), and infections at other locations (n = 6)
Chen et al (2004)	Most frequently presented with back and/or neck pain; motor deficits were the most common presenting sign	—	Diabetes mellitus (DM), chronic renal failure (CRF), alcoholism, liver cirrhosis
Christodoulou et al (2006)	All had persistent back pain; 4 presented with paraparesis	—	—
Connor et al (2013)	Axial pain (67.5%), focal weakness (55.8%), radiculopathy (29.9%), and myelopathy (5.2%)	—	—
Curry et al (2005)	Fever, pain, and motor deficits were present in the majority of cases	—	Intravenous drug use most common risk factor. Patients with spinal epidural abscess may be normothermic with normal WBC counts. Urgent surgery was more likely to be offered to patients presenting with neurologic deficits than with pain alone.
Darouiche et al (1992)	Backache (72%), radicular pain (47%), weakness of an extremity (35%), sensory deficit (23%), bladder or bowel dysfunction (30%), and frank paralysis (21%)	—	—
Davda et al (2014)	Back pain (100%), focal neurology (71%), and constitutional symptoms (fevers + weight loss) (44%)	—	—
de la Fuente Aguado et al (1992)	Fever and vertebral pain were the most constant clinical symptoms	—	—
Del Curling et al (1990)	Paraplegia and bladder dysfunction (43%), paraparesis (43%), and no presenting symptoms (14%)	—	Diabetes, acquired immunodeficiency syndrome (AIDs), sepsis
Furey et al (2014)	—	—	Significant risk factors for mortality: age >70 years ($P = .02$), hospitalization >5 days prior to surgery ($P = .04$), American Spinal Injury Association (ASIA) D ($P = .01$), DM ($P = .01$), methicillin-resistant *S aureus* (MRSA) sepsis ($P = .03$), and end-stage renal disease (ESRD; $P = .02$). Significant factors for neurologic Significant risk

Table 1. (continued)

Author (Year Published)	Presenting Symptoms	Duration of Symptoms Prior to Admission	Risk Factors
			factors for improvement: age <70 years (P = .01), neurologic deterioration less than 24 hours (P = .01), lumbar abscess not requiring fusion (P = .02), preoperative ASIA B or C (P = .01), and nondiabetics (P = .02)
Hadjipavlou et al (2000)	Paraplegia or paraparesis (100%)	Back pain generally preceded onset of neurological deficit	Infection in other body site most common. Epidural abscess of the thoracic spine had the highest incidence of paraplegia/paraparesis (P < .001). Thecal sac neurocompression has a greater chance of causing neurologic deficit in the thoracic spine (81.8%)
Kuker et al (1997)	Progressive sensorimotor deficits with back pain most common; urinary retention or loss of rectal sphincter control was a common presenting motor deficit	Pain preceded neurological deficits by median 2.7 months; pain occurred around same time neurological deficits	Pulmonary tuberculosis (TB), immunocompromised state
Lee et al (2011)	—	—	Local epidural injection for pain, DM, ESRD/chronic renal disease, liver cirrhosis
Liem et al (1994)	Back pain (90%), paresthesia (29%), incontinence (38%), fever with body temperature >101°F (29%), and/or severe (less than antigravity strength (71%)), moderate (10%) motor deficits, and no deficits (19%)	—	IV drug use (33%), DM (19%), prior surgery (14%), endocarditis (10%), HIV (10%), ESRD (10%), epidural catheterization (5%)
Nakase et al (2006)	Myelopathy or radicular pain	—	—
Patel et al (2014)	Pain and subjective fevers (50%) and/or weakness (47%)	—	IV drug use (39.1%), DM (21.9%)
Redekop et al (1992)	Severe back pain progressing to radicular pain to weakness to eventual paralysis (100%)	—	Thoracic cord anatomy (limited space) was a risk factor for earliest and most severe neurological deficits. Cellulitis or cutaneous abscess, respiratory infection, vertebral osteomyelitis.
Talia et al (2015)	Back pain (100%), progressive kyphosis (67%), fever (17%), limb weakness (78%)	—	—
Wang et al (2001)	Inferior paraparesis and/or back pain	—	Epidural analgesia (100%). Thoracic level was risk factor for poor paraparesis/paraplegia recovery with most survivors having poor recovery long term.
Wong et al (1998)	New spinal or radicular pain	—	Early diagnosis was associated with a better outcome

Reported nonmodifiable risk factors included immunosuppression (n = 5; 20%),[26,27,35-37] advanced age (n = 5; 20%),[25,26,32,34,36] liver cirrhosis (n = 2; 8%),[33,38] chronic kidney failure (n = 4; 16%),[12,26,37,38] and AIDS (n = 2; 8%).[27,35] History of diabetes mellitus was also reported as a risk factor for the development of thoracic SEA (n = 7; 28%).[27,28,33,35,36,38]

Radiographic, Microbiology, and Laboratory Findings

Diagnosis and monitoring (imaging and laboratory testing) for treatment response was described in 23 of the included articles (92%; Table 2). Use of imaging modalities (magnetic resonance imaging [MRI], computed tomography [CT], X-ray [XR]) was reported in 8 of these articles (32%): MRI,[22,24,26,27,31,39,40] CT,[25,27,40] and XR[29] imaging were noted in 6, 3, and 1 of the articles that met inclusion criteria, respectively. Curry et al demonstrated the utility of MRI with gadolinium contrast (71%) and CT myelography (29%) in the diagnosis of thoracic SEA among cases subsequently diagnosed with thoracic SEA at time of surgery.[21] Kuker et al further supported the utility of MRI with gadolinium in the conformation of thoracic SEA and went on to suggest that signal changes in T2-weighted images may be among the first signs of disc space infection.[25] Other diagnostic modalities

Table 2. Radiological and Microbiology Patient Workup.

Author (Year Published)	Radiology at Time of Admission	Microorganism(s) Isolated	Microbiology Notes	Pre- and Posttreatment C-Reactive Protein (Normal <5 mg/dL)	Pre- and Posttreatment Sedimentation Rate	Notes
Abdelrahman et al (2017)	—	S aureus most common (33.5%)	No significant age predilection (P = .074). Significant association with epidural abscesses (0.0001).	—	—	—
Aryan et al (2007)	—	S aureus (50%); S epidermidis (50%)	—	—	—	—
Boström et al (2008)	—	S aureus most common (85%); Streptococcus species (7%)	—	Elevated between 23 and >230 mg/dL (78%)	—	Elevated white blood cells (WBC) between 10.4 and 25.2 g/L (48%)
Christodoulou et al (2006)	—	Mycobacterium tuberculosis (TB) (100%)	—	Monitored preoperatively and postoperatively with regular monitoring to exclude active disease postoperatively	Monitored preoperatively and postoperatively with regular monitoring to exclude active disease postoperatively	—
Curry et al (2005)	Confirmed diagnosis via gadolinium-enhanced magnetic resonance imaging (MRI) T1 and T2 imaging (isointense/hypointense on T1 and hyperintense on T2) (71%). The remaining 29% were confirmed using computed tomography (CT) myelography.	Methicillin-resistant S aureus (MRSA) (31.2%); methicillin-sensitive S aureus (MSSA) (29.9%)	—	—	—	—
Darouiche et al (1992)	—	S aureus most common (65%)	All patients with positive abscess culture with S aureus had positive blood cultures	—	—	—
Davda et al (2014)	All had MRI at time of diagnosis	—	—	—	—	—
de la Fuente Aguado et al (1992)	Diagnosis was established with myelography or computerized axial tomography (CT)	—	—	—	—	—
Del Curling et al (1990)	—	S aureus (100%); 1 case also had concomitant S epidermidis	—	—	—	—
Dzupova et al (2017)	MRI (75.9%); CT (20.4%)	S aureus most common (53.7%)	—	—	—	—

Table 2. (continued)

Author (Year Published)	Radiology at Time of Admission	Microorganism(s) Isolated	Microbiology Notes	Pre- and Posttreatment C-Reactive Protein (Normal <5 mg/dL)	Pre- and Posttreatment Sedimentation Rate	Notes
Furey et al (2014)	—	MSSA and MRSA 2 most common (MSSA > MRSA); TB; gram negative rods	—	—	—	—
Hadjipavlou et al (2000)	—	S aureus most common	—	—	100% of patients tested and levels elevated preoperatively	Elevated WBC count (90%)
Kuker et al (1997)	MRI with gadolinium (T1/T2) (46%); signal change in T2-weighted images may be the first sign of disc space infection	S aureus most common; TB and Strep agalactia	—	100% of patients tested and levels elevated. All had resolution to normal levels following treatment.	100% of patients tested and levels elevated. All had resolution to normal levels following treatment.	Spondylodiscitis also present in all affected patients at same levels.
Lee et al (2011)	—	S aureus most common	Isolated in 70% of patients	—	—	—
Liem et al (1994)	CT with contrast myelography diagnostic in 11 of 11; MRI with gadolinium diagnostic in 14 of 14 cases	S aureus most common	Isolated in 86% of patients	—	100% of patients tested and levels elevated. All had resolution to normal levels following abscess resolution.	WBC count elevated (62%)
Nakase et al (2006)	—	S aureus most common; TB second most common MSSA (40%); MRSA (30%)	Isolated in 78% of patients	—	—	—
Patel et al (2014)	—			—	—	—
Redelkop et al (1992)	Plain radiographs predictive of purulent disc space infection (43%)	S aureus most common (64%) and each case sensitive to cloxacillin. Strep pyogenase (12%); and multiple organisms (8%)	Isolated in 96% of patients	—	—	—
Talia et al (2015)	—	S aureus most common; group B Strep; TB	—	—	—	—
Wang et al (2001)	MRI for diagnosis (78%)	S aureus most common (78%); coagulase negative (-) cocci (22%)	—	—	—	—
Wang et al (2012)	—	S aureus most common; coagulase (-) cocci	—	—	—	—
Wong et al (1998)	—	S aureus most common	—	—	ESR > 30 consistently present. Postoperatively monitored regularly to exclude active disease.	Surgery performed when ESR decreased and CRP was normal. Early diagnosis/treatment associated with better outcomes.
Yang et al (2016)	—	TB (100%)	—	—	—	—

utilized in the diagnostic process included myelography (n = 2; 8%)[24,26] and plain film radiographs (n = 1; 4%), although the latter was less specific for epidural abscess within the thoracic spine and more specific to purulent disc space infection.[28]

Seven studies reported the use of C-reactive protein (CRP) and/or erythrocyte sedimentation rate (ESR) in SEA disease identification and subsequent treatment response monitoring. Boström et al defined an elevated CRP as greater than 5 mg/dL with 78% of cases included in this study having a pretreatment CRP value between 23 and 230 mg/dL. Authors did not specifically define ESR thresholds before and after treatment; however, in the case of Kuker et al and Boström et al, the authors noted that elevated readings were defined as values above normal laboratory cutoff points (0-22 mm/hour for men and 0-29 mm/hour for women).[25,32] Similarly, Kuker et al found that pretreatment CRP values were elevated in 100% of reported cases.[25] ESR was found to be consistently elevated in patients presenting with thoracic epidural abscess as seen in Kuker et al (100%), Hadjipavlou et al (100%), Liem et al (100%), and Wong et al (100%). All reported elevation above normal range for pretreatment ESR values.[25,26,31,35] With the exception of thoracic epidural abscesses caused by tuberculosis, all investigators who monitored posttreatment CRP and ESR levels reported a decrease to normal values (n = 5; 19%).[25-27,31,33] Christodoulou et al, Nakase et al, and Wong et al reported the utilization of CRP and ESR monitoring in assessing epidural abscess response to treatment. In their respective reports all treated patients' CRP and ESR levels returned to normal with resolution of infection.[27,31,33] Similarly, increased white blood cell (WBC) counts with a return to normal levels following treatment was reported by Boström et al (48%), Hadjipavlou et al (90%), and Liem et al (62%).[26,32,35] Hadjipavlou et al reported concomitant spondylodiscitis in one third of patients with thoracic SEA (n = 11/33; 33%).[35]

The most frequently reported causative bacteria was *Staphylococcus aureus* (n = 18; 72%; Table 2).[3,21,22,25-31,33-40] Abdelrahman et al found no age predilection for infection with *S aureus* (P = .074).[36] Methicillin-sensitive *S aureus* (MSSA) was the causative bacteria in nearly 30% of patients reported by Curry et al and 40% of patients reported by Patel et al. Curry et el also found methicillin-resistant *S aureus* (MRSA; 31%) to be slightly more common than MSSA (30%) in patients admitted for thoracic SEA; thus, abscess culture and sensitivity profiles are necessary for effective treatment, as the pharmacological therapy for MSSA is ineffective against MRSA.[21] Less commonly reported bacterial strains cultured from thoracic epidural abscess aspirates included *S epidermidis*,[41] other coagulase negative *Staphylococcus* species,[32] gram negative rods, *Streptococcus agalactiae*,[25] and *Streptococcus pyogenes* (Table 2).[28]

While *Mycobacterium tuberculosis* (TB) has a very different bacterial lifecycle and spread relative to the other bacterial strains previously discussed, 3 included articles focused on this bacterial species as a cause of thoracic SEA.[27,33,42] Research in these studies found that these bacteria spread hematogeneously to the thoracic epidural space, as opposed to the majority of cases caused by *S aureus* that colonized the epidural space via direct extension. Additionally, these studies demonstrated that special aerobic culture on TB-specific media needed to be undertaken for proper diagnosis of this offending organism, as typical gram stain and culture would fail to diagnose the acid-fast bacterial species.

Pharmacological Management

Pharmacological management of thoracic SEAs was described in 13 of the included articles (52%). All 10 studies that reported pre- and postoperative antibiotic choice indicated that therapy was guided by sensitivity profiles obtained through bacterial culture (n = 10; 100%; Table 3).[20,26,27,30,32,33,35,40-42] Pharmacotherapy failure was described in 2 of the articles. Curry et al focused on the effect of failed medical management (pharmacotherapy) with subsequent delayed surgical treatment of epidural abscess.[22] Authors found that patients who received antibiotics and failed to clear their infection had significantly worse outcomes (ie, progression of neurological deterioration or reduced improvement in neurological symptoms following operation) compared with patients who received antibiotics and immediate surgical treatment (P < .005).[22] Patel et al identified 3 predictors of medical management failure: (1) CRP >115 (odds ratio [OR] 4.7, P = .045), (2) WBC >12.5 (OR 3.3, P = .045), and (3) positive blood cultures (OR 3.5, P = .035). Patients that did not have any of these risk factors at time of therapy were predicted to have an 8.3% risk of failing pharmacotherapy, whereas patients with 1 of 3, 2 of 3, or 3 of 3 of these risk factors were predicted to have a 35.4%, 40.2%, and 76.9% pharmacotherapy failure risk, respectively.[28]

Surgical Management and Patient Outcomes

Surgical treatment of thoracic SEA was discussed in 16 of the included articles (Table 4).[3,20,24-27,29,30,33-35,37,38,40,42] Patient outcomes following surgery were discussed in 15 of these articles.[3,20,24-27,29,30,33-35,37,38,40] Results of the following surgical techniques were reported in the included studies: laminectomy (n = 10; 63%), hemilaminectomy (n = 2; 13%), decompression and debridement/evacuation (n = 7; 44%), corpectomy with instrumentation (n = 2; 13%), and continuous irrigation through a laminotomy (n = 1; 6%). Surgical technique was based on the location of the SEA within the thoracic spine in 5 studies (31%), patient clinical status in 1 study (6%), and preoperative laboratory and imaging findings in 3 studies (19%). Seven articles discussed decision making criteria (Table 5).[3,20,27,32,35,38,42] In an earlier study by Wang et al, all patients were treated surgically with laminectomy and antibiotics pre- and postoperatively for variable durations. Of the 9 patients being treated for thoracic SEA, 7 had paraparesis/paraplegia at time of surgery and 6 did not recover following laminectomy, with 5 patient deaths during the postoperative follow-up period. Patients with severe preoperative motor dysfunction also had the most postoperative dysfunction with no

Table 3. Pharmacological Management.

Author (Year Published)	Antibiotic Therapy	Antibiotic Duration	Notes
Aryan et al (2007)	IV antibiotics pre- and postoperatively based on culture sensitivity	At least 6 weeks	No recurrence of bone or hardware infection among patients treated with antibiotics
Boström et al (2008)	Clindamycin was drug of choice in majority of *Staphylococcus* infections	—	—
Christodoulou et al (2006)	Antituberculous treatment preoperatively and for up to 9 months postoperatively. Regimen: streptomycin (1 g/day for 1 month and 1 g every alternate day for 1 month); rifampicin (600 mg/day for 9 months); isoniazid (300 mg/day for 9 months); and pyrazinamide (1.5 g/day for 2 months). Streptomycin and pyrazinamide replaced after 2 months and switched by ethambutol (1.2 g/day) for another 7 months.	9 months	All patients began antituberculosis medication preoperatively and liver and renal function monitored regularly during therapy
Connor et al (2013)	Tailored to bacterial sensitivity from cultures. All had intravenous (IV) pre- and postoperatively.	Median 6 weeks (2-24 weeks)	—
Curry et al (2005)	—	—	Patients who received antibiotics and had delayed surgical management had significantly more poor outcomes than those treated early surgically (increased morbidity and mortality) ($P < .005$)
Del Curling et al (1990)	—	Median 2 weeks IV (1.5-6 weeks) followed by oral antibiotics (0-6 weeks)	—
Hadjipavlou et al (2000)	Clindamycin and ofloxacin were predominantly used based on culture sensitivities. If blood-brain barrier (BBB) had suspected compromise use of vancomycin and ceftazidime was initiated.	—	—
Liem et al (1994)	Tailored to bacterial sensitivity from cultures. All had IV pre- and postoperatively.	6-16 weeks	Duration determined by monitoring clinical course, osteomyelitis status, serial magnetic resonance imaging (MRI) studies, and serial erythrocyte sedimentation rate (ESR) monitoring
Nakase et al (2006)	All patients received appropriate IV antibiotics pre- and postoperatively	—	—
Patel et al (2014)	—	—	Identified 4 predictors of failed medical (pharmacotherapy) management with need for surgical management: diabetes mellitus (DM) (odds ratio [OR] 2.8, $P = .057$); C-reactive protein (CRP) > 115 (OR 4.7, $P = .45$); white blood cell count (WBC) > 12.5 (OR 3.3, $P = .045$); and positive blood cultures (OR 3.5, $P = .035$). If patient had none of 4: 8.3% failure risk; if 1/4 35.4% failure; if 2/4: 40.2% failure risk; and 3-4: 76.9% failure risk.
Wang et al (2001)	Ceftriaxone + gentramycin; methic + fusidin; dicloxacillin +/- rifampin depending on sensitivities from cultures	—	—
Wang et al (2012)	Dicloxacillin predominantly used based on sensitivities	—	—
Yang et al (2016)	RIPE: rifampicin (450 mg); isoniazid (INH) (300 mg), pyrazinamide (1500 mg), ethambutol (750 mg) and pyrazinamide (1500 mg)/day	—	—

Table 4. Surgical Management and Outcomes.

Author (Year Published)	Percentage of Cases Treated Surgically	Surgical Technique	Surgical Notes	Patient Postoperative Outcomes
Boström et al (2008)	100%	Laminectomies (ventral and dorsally located abscesses), Hemilaminectomies (dorsally located)	Computed tomography (CT) guided puncture accompanying surgery	—
Christodoulou et al (2006)	100%	Radical surgical debridement, anterior decompression, and interbody arthrodesis	Titanium mesh cage system. Corticocancellous bone grafts used to fill cage and structural stabilization anteriorally from anterior instrumentation.	Back pain resolved in all but 1 patient. 75% of patients with preoperative paraparesis had improved functional outcomes (reduced neurological deficits).
Connor et al (2013)	80%	Posterior laminectomy	Standard practice to operate when case presents with acute motor strength loss or bowel and/or bladder control ("surgical emergency")	Improved outcomes (decreased neurological or sensory signs and symptoms) in 79.2%, minimal in 8.3%, worsening in 12.5%. Increased age ($P = .04$) and greater premorbid weakness ($P = .012$) associated with worse postoperative outcomes.
de la Fuente Aguado et al (1992)	66%	Laminectomy	—	Outcome was favorable in the patients who underwent surgery, but the patients treated conservatively had a fatal outcome.
Del Curling et al (1990)	100%	One patient had a posterolateral costotransversectomy at T7 and 5 underwent standard laminectomies	Half of all surgeries found pus and granulation tissue in the epidural space (52%). Preoperative course did not correlate with operative pus/granulation tissue findings.	Five of the 6 thoracic SEAs were treated surgically with improvement in symptoms (paraplegia to paraparesis, paraparesis to normal, or a reduced number of neurological deficits). Length of antibiotic or surgical treatment modality was not associated with the severity of postoperative symptoms or final neurological outcome.
Furey et al (2014)	100%	Decompression and evacuation for posterior epidural abscesses with no structural grafting. Anterior decompression with structural allograft followed by a staged, posterior instrumented fusion for anterior located abscess.	Six anterior abscesses and 6 posterior abscesses	Risk factors for mortality were age >70 years old ($P = .01$), neurological deficit >5 days ($P = .04$), American Spinal Injury Association (ASIA) D ($P = .01$), diabetes mellitus (DM; $P = .01$), methicillin-resistant S aureus (MRSA) sepsis ($P = .03$), and end-stage renal disease (ESRD; $P = .02$).
Hadjipavlou et al (2000)	—	Decompression with or without fusion	Granulation tissue found during surgery in 2 cases	Surgery was more effective in preventing postinfection kyphosis and chronic back pain than medical management alone.
Kuker et al (1997)	66%	Two hemilaminectomies (1 with revision to laminectomy during second surgery); 2 laminectomies; 2 CT-guided biopsies with drainage alone	—	Over half (66%) had improvement of symptoms postoperatively (n = 1; 17%), slight improvement from initial symptoms, major improvement or recovery (n = 3; 50%) to baseline neurological function.
Lee et al (2011)	—	Laminectomy	Continuous irrigation through laminectomy	Low back outcome score (LBOS), Visual Analog Scale (VAS) score, and Frankel grade showed significant improvement in most patient.
Liem et al (1994)	95%	Laminectomy with drainage 11 (52%), of which 2 deteriorated requiring anterior corpectomy; transthoracic corpectomy and fixation (n = 5; 24%); costotransversectomy (n = 1; 5%); or percutaneous aspiration (n = 1; 5%)	Purulent fluid found in 2 people. Tobramycin-impregnated methylmethacrylate with central metal rod construct was used. All patients had postoperative bracing. Postoperative slippage of construct due to technical error in placing instrumentation seen in 2 patients. One patient required revision of rib graft due to displacement.	Postoperative outcomes worse in patients who presented with worse symptoms (increased muscle weakness, paraparalysis/paraplegia). Three patients deceased at follow-up (6-24 months) due to sepsis complication in hospital. Patients with anterior pathology who initially had laminectomy did poorly generally throughout. Patients with severe symptoms did better if rapid decompression was initiated within 24 hours.
Nakase et al (2006)	—	Radical surgical debridement with stable reconstruction (with or without instrumentation)	First stage: anterior debridement or drainage + application of external orthosis postoperatively. Between stage antibiotic treatment for all cases. Second stage: complete debridement of all necrotic bone and soft tissues, and stable reconstruction with or without instrumentation.	No evidence of recurrence and/or residual infection in any surgically treated patients. All patients except for one returned to normal functional status.

(continued)

Table 4. (continued)

Author (Year Published)	Percentage of Cases Treated Surgically	Surgical Technique	Surgical Notes	Patient Postoperative Outcomes
Patel et al (2014)	—	Laminectomy, anterior discectomy and fusion, corpectomy, or posterior spinal instrumentation with fusion based on severity and location of pathology	—	Irrespective of treatment, motor score (MS) (Asia Motor score) improved by 3.37 points. More than 41% of patients treated medically (antibiotics alone) failed and required delayed surgical treatment. Patients who failed medical management of epidural abscess and had delayed surgery had a significantly worse improvement of MS compared with those treated with immediate surgery. C-reactive protein (CRP) greater than 115, white blood count greater than 12.5, and positive blood cultures predict medical failure.
Talia et al (2015)	—	Single stage radical debridement with instrumentation and fusion	Posterolateral transpedicular approach	No recurrence of infection at 12-month follow-up in any surgically treated patients. Postoperatively there was a reduction in postoperative pain scores (VAS 8.56-3.75) at 3 months. Increased duration of antibiotic therapy was not associated with greater improvement of ASIA motor score or recurrence rate and presurgical ASIA motor score was a stronger predictor of 6- and 12-month motor score outcome.
Wang et al (2001)	—	Laminectomy	—	75% experienced paraparesis/paraplegia at some stage, 67% did not recover and suffered permanent paresis, and 11% suffered permanent bowel and/or bladder dysfunction. Five cases died during follow-up period and more severe preoperative symptoms (paraparalysis) were associated with more severe postoperative outcomes (paraparalysis, bowel and bladder dysfunction, death).
Wang et al (2012)	—	Laminectomy	—	Overall recovery for patients with paraparesis/paraplegia after epidural abscess was 20% for all levels. No patients with paraparesis/paraplegia from thoracic abscess recovered versus 50% recovery in lumbar epidural abscess.
Yang et al (2016)	100%	Decompression	Surgery was performed when erythrocyte sedimentation rate (ESR) decreased and C-reactive protein (CRP) was within normal range	ASIA motor scores were improved in all patients postoperatively with mild increase in the Cobb angle, but satisfactory spinal stabilization was achieved in these patients. Minimally invasive spinal canal decompression with antibiotics were effective in treating thoracic epidural infection with spinal cord compression.

Table 5. Decision-Marking Criteria.

Author (Year Published)	Decision-Making Criteria Used
Boström et al (2008)	Abscesses located ventrally or dorsally were treated with laminectomies. Abscesses located dorsally were treated with hemilaminectomies.
Connor et al (2013)	Standard practice to operate when case presents with acute motor strength loss or bowel and/or bladder control ("surgical emergency").
Furey et al (2014)	Decompression and evacuation for posterior epidural abscesses with no structural grafting. Anterior decompression with structural allograft followed by a staged, posterior instrumented fusion for anterior located epidural abscess.
Hadjipavlou et al (2000)	If primary epidural abscess was present emergency laminectomy was performed. If there was instability present in these cases, posterior instrumentation and fusion was recommended. If epidural abscess was present secondary to spondylodiscitis and the abscess was anteriorly located then posterior instrumentation, deformity correction, and fusion were recommended in combination with anterior decompression. In the case of posterior abscesses secondary to spondylodiscitis, again, emergent laminectomy, posterior stabilization and fusion, and corrective deformity was recommended in combination with anterior decompression and fusion.
Nakase et al (2006)	Instrumentation and stabilization when structural instability was present.
Patel et al (2014)	Severity and location of the pathology dictated treatment approach.
Yang et al (2016)	Surgery was performed when erythrocyte sedimentation rate decreased and C-reactive protein was within normal range.

association between length of antibiotic treatment postoperative and patient recovery.[30] Later studies by Wang et al found similar poor rates of recovery (20%) in patients with severe preoperative neurological deficit presenting with SEA of the cervical, thoracic, and/or lumbar spine. These reports showed isolated thoracic SEA had no recovery versus 50% recovery rates in patients with isolated lumbar SEA.[40] Thalia et al further demonstrated that a patient's preoperative American Spinal Injury Association (ASIA) motor score was a better predictor of postoperative ASIA motor scores in comparison to antibiotic duration or preoperative risk factors.[29] Of the 6 thoracic patients included in the overall study, 2 had improvement in ASIA motor score (1 by 1 point and 1 by 3 points) and 4 had no change at 3 months postoperation. At 12 months, 4 (67%) had improved ASIA motor scores.

Patel et al compared patients treated with antibiotics alone (group 1), immediate surgery (laminectomy, anterior discectomy and fusion, corpectomy, or posterior spinal instrumentation with fusion) and antibiotics based on severity and location of SEA (group 2), or antibiotics followed by delayed surgery with antibiotics due to treatment failure (group 3). These studies found that 41% of patients treated with antibiotics alone failed to resolve the infection and eventually required surgical intervention. Irrespective of surgical approach, all patients treated surgically immediately had improvement in ASIA motor score (mean improvement of 3.37 points). Patients who failed medical management and required delayed surgical intervention had significantly worse outcomes (lower motor scores or increased pain postoperatively) compared with patients treated with immediate antibiotics and surgery. Patel et al also found that significant predictors of medical management failure were a CRP level >115, a WBC count >12.5, and blood cultures positive for bacteria (bacteremia).[3] Similarly, de la Fuente Aguado et al reported favorable outcomes in the 2 (66%) thoracic SEA cases treated with immediate laminectomy compared with the 1 case (33%) that was treated with conservative management and had a fatal outcome.[24]

Connor et al reported that surgical interventions were initiated immediately whenever thoracic SEA cases presented with acute motor strength loss.[20] Patients treated with posterior laminectomy had improved, stable, or worsening neurological outcomes at follow-up in 79%, 8%, and 13% of cases, respectively. Older age ($P = .04$) and greater premorbid weakness ($P = .012$) were associated with worse postoperative outcome. Furey et al analyzed data on 12 cases of thoracic SEAs treated with either surgical decompression and evacuation for posterior SEA or anterior decompression with structural allograft and staged posterior instrumented fusion for anterior SEA. They found no difference in outcome or survival between location and surgical approach used.[38] Risk factors associated with mortality in this study were age >70 years ($P = .01$), neurological deficits present >5 days prior to surgery ($P = .04$), a preoperative ASIA D motor score ($P = .01$), diabetes mellitus (DM; $P = .01$), MRSA sepsis ($P = .03$), and end-stage renal disease (ESRD; $P = .02$).[38] Of note, the authors were surprised by the aforementioned increase in mortality associated with lower presurgical ASIA D score. One potential explanation for this could be delayed surgical intervention in patients with less severe symptoms and subsequently worse outcomes associated with the delay. Liem et al also found that patients with more severe preoperative symptoms did better if rapid decompression occurred within 24 hours of symptoms compared with patients who had delays in surgical decompression greater than 24 hours from time of onset. Of the 11 patients treated with laminectomy and drainage (52%), 2 of them deteriorated and required anterior corpectomy. The remaining 10 patients were treated with transthoracic corpectomy and fixation (n = 5; 24%), costotransversectomy (n = 1; 5%), or percutaneous aspiration (n = 1; 5%). Patients with anterior pathology who initially underwent laminectomy did poorly compared with patients where the anterior lesion was approached directly from an anterior approach. Development of sepsis (n = 3; 14%) during initial hospitalization was fatal in all cases and patients

who presented with worse neurological symptoms preoperative had worse outcomes.[26]

No included articles compared surgical treatment approach efficacy or specifically compared outcomes associated with varied surgical approaches. As noted above, Liem et al did find more favorable outcomes with a direct approach compared with a posterior laminectomy in patients with anterior thoracic SEAs; however, no major comparisons were made between other surgical techniques used for posteriorly located abscesses, and post hoc analysis for anterior approach was limited.

Discussion

Thoracic SEA is a serious and potentially life-threatening medical emergency if left untreated. This systematic review compiled previously published studies to bridge gaps in relevant clinical knowledge. To this aim, the authors included 25 articles and extracted information on outcomes and treatment of thoracic SEA. Information from included articles was grouped into 1 of 5 categories: (1) clinical presentation, duration of symptoms, and risk factors; (2) radiological, microbiology, and laboratory findings; (3) pharmacological management; (4) surgical management; and (5) patient outcomes.

Surgical Management and Patient Outcomes

To our knowledge, no formalized guidelines exist for the treatment of thoracic SEAs, specifically. Prior systematic reviews on SEAs at all levels have compared treatment modalities by spatial orientation around the spinal cord (anterior, posterior, posteriolateral). However, these prior approaches have not focused to any large extent on anatomical-specific outcomes that are relevant to the thoracic spinal cord level specifically (faster rate of cord compression, higher incidence of paraparesis/paraplegia compared with other levels, worse recovery rates compared with other levels). Rather, treatment approach in the majority of included cases involved 3 components: (1) broad-spectrum empiric antibiotics after abscess biopsy, (2) targeted antibiotics based on cultured sensitivity profiles for the bacteria, and (3) surgical decompression +/- instrumentation. Results from included studies further demonstrate that patient outcomes between studies, even when presenting with similar preoperative neurological deficits, are highly variable. Heterogeneity in patient outcomes highlights the need to better understand which approaches to surgical management of thoracic SEAs produce the best patient outcomes.

None of the included articles directly compared different surgical approaches for treatment of thoracic SEAs. While Liem et al found improved outcomes when anterior located thoracic SEAs were treated using an anterior approach versus a posterior laminectomy, no detailed comparisons were made between outcomes associated with different surgical approaches. Surgical complications were not compared between the types of surgery. Results obtained from this systematic review underscore a need for randomized clinical

studies aimed at comparing efficacy of different surgical approaches based on location of the abscess. It is important to note that the included studies did not characterize the preoperative spinal stability or alignment (ie, in cases of osteomyelitis) well enough to make meaningful conclusions about types of surgical intervention. However, from the literature and in the authors' experience, it is clear that reconstruction with stabilization should be added in cases of spine instability and kyphosis.

Results outlined in this systematic review can aid spine surgeons in developing methodologies capable of addressing our current gaps in knowledge. First, the majority of studies included reported improved outcomes with immediate surgical intervention and antibiotics,[3,20,24,26,38] and as previously discussed, up to 55% of patients presenting with SEAs are initially misdiagnosed with significant delays in treatment.[9] Furthermore, as noted above, results presented by Hadjipavlou et al and Abdelrahman et al on neurological deficits and neurological recovery following spinal decompression for SEA, respectively, demonstrated a significantly higher rate of paraplegia/paraparesis prior to surgery and a significantly lower recovery rate following surgical decompression in patients with SEAs at the thoracic level compared with other levels.[35,36] In light of these findings, early diagnosis and aggressive surgical decompression when neurological deficits are present is a reasonable approach and can help reduce the greater likelihood of persistent morbidity in this patient population. With that said, a large degree of bias exists within the current literature regarding patients included in published studies (more often sicker patients with greater neurological deficit at time of admission). This selection bias in patient population complicates external validity to a less or nonneurologically impaired patient population. Clinical judgement and vigilance obtained through recognition of characteristic signs and symptoms in addition to laboratory and radiological findings can aid spine surgeons in increasing speed of thoracic SEA diagnosis and management. Second, risk factors associated with increased mortality (ASIA D score, DM, MRSA sepsis, ESRD, age >70, and neurological deficits present >5 days prior to surgery) can aid in the design of surveillance programs for spine surgeons. For example, patients with multiple risk factors for the development of a thoracic SEA following spine surgery could be educated on warning signs associated with development of thoracic SEAs (back pain, fever, paraparesis, and other signs of neurological deficit) with the goal of quicker diagnosis and surgical intervention. Third, risk factors for medical management failure could be adapted into an algorithm to predict medical management failure based on risk factors and presenting symptoms. This algorithm could stratify immediate surgical management with medical management versus permissive medical management alone in patients who are predicted to have a low calculated predictive risk of medical management failure based on a predetermined threshold. This would allow spine surgeons to optimize treatment outcomes, while also addressing the potential for unnecessary costs associated with

surgical intervention among patients with low risk of medical management alone failure.

Future studies with a larger sample size, greater statistical power, and randomized controls could yield valuable data to power statistical models capable of predicting which patients are at greatest risk for developing thoracic SEAs, more likely to fail medical management, and which surgical approaches are most efficacious for thoracic SEAs accounting for approach (anterior, posterior, anterolateral). While the execution of a randomized controlled trial in this patient population is difficult, if not impossible, prospective comparative trials are certainly within the realm of possibility at tertiary centers.

Clinical Presentation and Duration of Symptoms

Recognizing signs and symptoms associated with the presence of thoracic SEAs is essential for the initial diagnosis and subsequent timely management. Despite characteristic patient presentation (back pain, fever, and neurological deficit),[26,32] the diagnosis of thoracic SEA is often missed and patients are not adequately diagnosed during the initial encounter.[9] One possible reason for the diagnostic error is primary care and emergency medicine physicians reluctance to order expensive MRI capable of visualizing abscess foci. In this case, physician education would be essential for reducing diagnostic errors in patients presenting with thoracic SEAs. Importantly, the duration of symptoms prior to time of admission can be quite variable and a high level of suspicion is warranted, especially among patients with relevant risk factors (intravenous drug use, AIDS and immunocompromised, DM, and chronic renal failure). More controlled studies with larger patient cohorts would afford researchers an adequate sample size (beta) for logistical regression models capable of predicting adverse events of interest (medical management failure, development of thoracic SEA, patient mortality, etc). Additionally, a larger controlled patient population would allow researchers to better characterize initial presenting symptoms (signs, symptoms, duration) with a standardized data-collection protocol, rather than the amalgam of varied research tools presented in this systematic review. Finally, more specific recommendations on how long to continue antibiotics after ESR/CRP laboratory values normalize would provide clinicians more definitive guidance on needed length of pharmacotherapy in patients presenting with thoracic SEA.

Radiological, Laboratory, and Microbiology Findings

Aside from the initial patient history and physical, radiological and laboratory findings are often the only other data points available in guiding clinical decision making. CRP and ESR are 2 commonly monitored inflammatory markers used before and after surgical/antibiotics. CRP was nearly always elevated in patients presenting with thoracic SEAs with levels decreasing to baseline indicative of a successful treatment response. Based on results of this review, all patients with suspected thoracic SEA should undergo bloodwork to measure CRP,

ESR, and WBC. MRI with gadolinium contrast and/or CT imaging with or without myelography were found to have high sensitivity and specificity capable of determining treatment response following antibiotics and surgical decompression. As such, MRI and CT are reasonable initial diagnostic modalities and can aid spine surgeons in localizing the thoracic abscess within the epidural space. As mentioned above, future studies aimed at comparing the efficacy between different surgical techniques based on thoracic SEA location (anterior, posterior, etc) will require a detailed knowledge of abscess location prior to preparation for surgical approach. Furthermore, serial monitoring of ESR, CRP, WBC, and/or MRI/CT has the potential to guide duration of antibiotic treatment. This duration is important given the rise in antibiotic resistance, antibiotic stewardship programs, and the cost associated with longer duration of unnecessary antibiotics following SEA resolution.[39-41] Most often infections of the thoracic epidural space were caused by *S aureus*, although *M tuberculosis*, other coagulase negative *Staphylococcus*, gram negative rods, and mixed microbial infections are reported to a lesser extent. With this in mind, empirical therapy following thoracic SEA biopsy should include broad spectrum antibiotics normally used to cover the most commonly implicated microorganisms (MSSA, MRSA, other coagulase negative *Staphylococcus* species).

Pharmacological Management

Pharmacological therapy was based on cultures obtained from thoracic SEA biopsy. Biopsy should be obtained prior to initiation of pharmacotherapy rather than initiating broad spectrum antibiotics before sample collection, as the latter can compromise ability to culture aspirates and limits ability to obtain bacterial sensitivity profiles for more tailored medical management. Length of antibiotics for treatment of abscess varied by study, but a number of reports monitored serial ESR and CRP laboratory values to monitor infection response, with slower responses requiring longer courses of antibiotic therapy.[24,27] As mentioned above, with growing concern over antimicrobial resistance exceeding our ability to produce novel antibiotics to counter such resistance, it is important to protect our antimicrobial arsenal from unnecessary resistance caused by inappropriate antibiotic use.

Use of pharmacological therapy (medical management) was ubiquitous across studies; however, the literature is largely lacking in terms of comparison between medical management alone for thoracic SEA, specifically, versus immediate surgical intervention with focused antibiotic treatment. Importantly, Patel et al reported rates as high as 41% for failure of antibiotic therapy alone without combined surgery.[3] Based on cases presented by Patel et al, patients who failed antibiotic therapy and needed delayed surgery for treatment of abscess had a statistically significant worse outcomes compared with patients treated immediately at admission with decompression (ie, irreversible neurological deficits). Future studies with a larger patient population with thoracic SEAs is necessary to better

characterize factors associated with failure of medical management and subsequent risk of worsening neurological sequelae.

Limitations and Future Study

To address this clinical entity, investigators initially aimed to further characterize thoracic SEAs based on presentation and clinical workup. In addition, they aimed to discuss surgical considerations, specifically, the importance of surgical and/or medical management timing in relation to patient risk factors and subsequent patient outcomes, general rates of neurological recovery following immediate versus delayed surgical management, and specific surgical approaches. However, several limitations became evident during the systematic review process. First, despite initial objectives, investigators soon found that much of the past and current literature does not stratify patient findings based on spinal cord level. As such, synthesis of extracted data was limited. Second, the majority of articles yielded from the initial database query process were simple case reports and did not meet the eligibility criteria for inclusion in this study. Our final smaller list of eligible articles provided some invaluable information with regard to patient risk factors, presentation, microorganisms involved, and response to varied treatment approaches. Limited overlap between content analyzed in each included article was less than ideal for comparison between studies. However, despite limited overlap in protocol and study focus, meaningful results capable of informing clinical decision making were still able to be extracted from included studies and discussed in the current review. Third, because thoracic SEAs are a fairly rare clinical entity seen at any one regional research center, enrolling enough patients for randomized clinical trials or larger cohort studies would be difficult and likely require a multicenter collaboration and multiple years of enrollment, data collection, and analysis. Fourth, the majority of included articles did not carry out any sort of exhaustive statistical analysis to identify significance factors, odds ratios, group mean differences, and other metrics useful in patient safety and quality improvement. Last, external validity and generalizability is stymied, in part, by a selection bias in favor of including patients with greater neurological deficit rather than patients without significant impairment at time of admission. Future studies involving a greater degree of variance in patient population (age, presenting neurological status at time of admission, comorbid disease history) as well as a greater sample size can further aid spine surgeons in attaining improved outcomes in patients presenting with thoracic SEA.

Conclusion

The present systematic review addresses a significant gap in the field of spine research. For the first time researchers have focused specifically on SEAs of the thoracic level, as opposed to previously published general analysis of SEAs as a whole. Given the fact that thoracic SEAs are quicker to progress and compress vital cord structures, the combination of results presented and relevant clinical experience can be used by spine surgeons and other providers to reduce morbidity and mortality in their patient populations. Based on the results, investigators recommend early MRI imaging of the spine, laboratory workup (ESR/CRP, complete blood count), abscess culture followed by empiric antibiotics, and immediate surgical decompression when neurological deficits are present.

Appendix

Included Studies

Author (Year Published)	Study Type	Number of Patients Total	Number of Patients With Isolated Thoracic Level
Abdelrahman et al (2017)	Retrospective	600	27
Aryan et al (2007)	Retrospective	15	2
Boström et al (2008)	Retrospective	46	27
Chen et al (2004)	Retrospective	17	3
Christodoulou et al (2006)	Retrospective	12	8
Connor et al (2013)	Retrospective	77	20
Curry et al (2005)	Retrospective	48	7
Darouiche et al (1992)	Retrospective	43	9
Davda et al (2014)	Retrospective	34	16
de la Fuente Aguado et al (1992)	Retrospective	4	3
Del Curling et al (1990)	Retrospective	29	6
Dzupova et al (2017)	Retrospective	54	14
Furey et al (2014)	Retrospective	42	12
Hadjipavlou et al (2000)	Retrospective	101	11
Kuker et al (1997)	Retrospective	13	6
Lee et al (2011)	Retrospective	31	22
Liem et al (1994)	Retrospective	21	21
Nakase et al (2006)	Retrospective	9	4
Patel et al (2014)	Retrospective	128	50
Redekop et al (1992)	Retrospective	25	7
Talia et al (2015)	Retrospective	9	6
Wang et al (2001)	Retrospective	19	9
Wang et al (2012)	Prospective	102	12
Wong et al (1998)	Retrospective	7	3
Yang et al (2016)	Retrospective	31	27

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