An institutional series and contemporary review of bacterial spinal epidural abscess: current status and future directions

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Object. Over the past decade, the incidence of bacterial spinal epidural abscess (SEA) has been increasing. In recent years, studies on this condition have been rampant in the literature. The authors present an 11-year institutional experience with SEA patients. Additionally, through an analysis of the contemporary literature, they provide an update on the challenging and controversial nature of this increasingly encountered condition.

Methods. An electronic medical record database was used to retrospectively analyze patients admitted with SEA from January 2001 through February 2012. Presenting symptoms, concurrent conditions, microorganisms, diagnostic modalities, treatments, and outcomes were examined. For the literature search, PubMed was used as the search engine. Studies published from January 1, 2000, through December 31, 2013, were critically reviewed. Data from articles on methodology, demographics, treatments, and outcomes were recorded.

Results. A total of 106 patients with bacterial SEA were identified. The mean $\pm$ SD age of patients was 63.3 ± 13.7 years, and 65.1% of patients were male. Common presenting signs and symptoms were back pain (47.1%) and focal neurological deficits (47.1%). Over 75% of SEAs were in the thoracolumbar spine, and over 50% were ventral. Approximately 34% had an infectious origin. Concurrent conditions included diabetes mellitus (35.8%), vascular conditions (31.3%), and renal insufficiency/dialysis (30.2%). The most commonly isolated organism was *Staphylococcus aureus* (70.7%), followed by *Streptococcus* spp. (6.6%). Surgery along with antibiotics was the treatment for 63 (59.4%) patients. Surgery involved spinal fusion for 19 (30.2%), discectomy for 14 (22.2%), and corpectomy for 9 (14.3%). Outcomes were reported objectively; at a mean $\pm$ SD follow-up time of 8.4 ± 26 weeks (range 0–192 weeks), outcome was good for 60.7% of patients and poor for 39.3%. The literature search yielded 40 articles, and the authors discuss the result of these studies.

Conclusions. Bacterial SEA is an ominous condition that calls for early recognition. Neurological status at the time of presentation is a key factor in decision making and patient outcome. In recent years, surgical treatment has been advocated for patients with neurological deficits and failed response to medical therapy. Surgery should be performed immediately and before 36–72 hours from onset of neurological sequelae. However, the decision between medical or surgical intervention entails individual patient considerations including age, concurrent conditions, and objective findings. An evidence-based algorithm for diagnosis and treatment is suggested.
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KEY WORDS • spinal epidural abscess • CNS infection • spine surgery •
treatment • management algorithm

ASPINAL epidural abscess (SEA) is a suppurative infection localized to the extradural space.^{11,24} Although SEAs are quite rare, their incidence has been rising gradually over the recent decade,^{10,11,19,24,33,34} possibly associated with increasing intravenous drug abuse, expanding use of spinal instrumentation, and an aging population with multiple concurrent conditions.^{11,19,24} Clinical presentation is typically characterized by back or neck pain, fe-

ver, and focal neurological deficits; however, recognition and diagnosis of SEAs can often be arduous.^{19,21,24} SEAs can be either primary or secondary. Primary SEAs result from hematogenous spread of pathogens from a distant focus into the epidural space; secondary SEAs occur after spinal trauma, injections, surgery, or direct inoculation of a pathogen into the epidural space.^{4,6} The pathophysiology of primary and secondary SEAs might be closely associated with comorbidities.

In the past, treatment has consisted of urgent surgical decompression and abscess drainage along with multiple weeks of intravenous antibiotic therapy.^{10,19,23,33} Decompression surgery has involved laminectomy, disc-

Abbreviations used in this paper: ASIA = American Spinal Injury Association; MRSA = methicillin-resistant *Staphylococcus aureus*; SEA = spinal epidural abscess.

ectomy, fusion, and corpectomy.^{4,15,19} Decompression also serves as a way to identify the causative microbe so that appropriate antibiotic therapy can be expeditiously administered.^{4,15,37} In select patients with mild back pain and without neurological deficits, antibiotic treatment and immobilization alone can be sufficient therapy;^{4,11,36,37} these patients, however, need close monitoring because immediate operative intervention can become necessary in cases of subsequent neurological deterioration.^{4,23,32}

Bacterial SEAs have been characterized in several case reports and case series; their epidemiology, predisposing conditions, diagnostic modalities, and approaches to management have all been described. We analyzed such patient data over an 11-year period and interconnected the results with those in the literature. Our review of the contemporary literature provides an update and sheds light on a condition that has been of great interest and challenge to neurosurgeons.

Methods

Retrospective Study

After receiving institutional review board approval, we searched the electronic medical record database at Summa Health System for all patients with a discharge diagnosis of SEA from January 2001 through February 2012. The search identified 160 patients. We excluded 54 patients: 46 patients had been readmitted for the original SEA (Fig. 1), and 8 lacked pertinent information or had been transferred to an alternate facility. For the 106 patients included in the study, each chart was reviewed from admission to discharge and assessed for presenting symptoms, predisposing factors, infecting microorganism, mode of diagnosis, mode of treatment, and outcome.

Literature Review

A literature search was conducted through the National Library of Medicine search engine, PubMed. Our aim was to find large retrospective or prospective studies of patients with bacterial SEA. Because we intended to obtain recent studies, particularly those published after the last meta-analysis published in 2000,³⁴ we included only studies that had been published from 2000 on. We excluded case reports and review articles. We included only articles published in the English language and in peer-reviewed journals. Findings from our study were compared with those from studies reported in the literature.

We began the query with the search term “spinal epidural abscess” limited to publications from January 1, 2000, through December 31, 2013. The initial search produced 1264 results. After limiting the search to publications in the English language (1087 articles), abstracts of these articles were reviewed by 3 authors (F.S., K.S., and S.Z.). This review yielded articles for detailed review and inclusion in the analysis. After examining the reference lists from the selected articles for other relevant articles, we included a total of 40 studies in the updated review. The remaining articles were not centered on SEA, discussed a different disease entity, were case reports, or

were literature reviews. Data from the chosen articles on research methodology, patient age, demographics, treatments offered, and outcomes at mean follow-up time were recorded.

Results

Retrospective Study

Of the 106 patients evaluated, most (69 [65.1%]) were male, and the mean $\pm$ SD age of patients was 63.3 ± 13.7 years (range 33–89 years). The most frequent presenting symptoms were back pain in 48 (45.3%) and focal neurological findings in 48 (47.1%). Of the patients who had focal neurological findings at initial presentation, 25 (24.5%) complained of paralysis and paresis of the extremities and 23 (22.5%) complained of paresthesias and pain in the extremities. Other presenting signs or symptoms were fever/chills in 34 (33%), urinary or bowel incontinence in 18 (17.6%), altered mental status or lethargy in 13 (12.7%), neck pain in 8 (7.8%), and nausea and/or vomiting in 5 (4.9%). These findings are summarized in Table 1.

We designated SEA as primary if the patient had no history of spine surgery, injections, or any other invasive spinal procedure. In our study, the cause of SEA was primary for 85 (80.2%) patients and secondary for 21 (19.8%). Table 2 summarizes results regarding abscess locations. Among primary SEAs, 40 (47.1%) were lumbar, 29 (34.1%) were thoracic, 15 (17.6%) were cervical, and 1 (1.2%) was sacral. Among secondary SEAs, 15 (71.4%) were lumbar, 4 (19.0%) were thoracic, 1 (4.7%) was sacral, and 1 (4.7%) was cervical. Of clinical relevance, 30 (37.5%) of SEAs were dorsal and 47 (58.8%) were ventral. Primary SEAs were slightly more likely than secondary SEAs to involve more levels (2.05 vs 1.81, respectively).

For 36 (34.0%) of the 106 patients, an infectious ori-

Fig. 1. Flow chart showing inclusion and exclusion criteria for the original 160 patients with a discharge diagnosis of SEA on the institutional electronic medical record.

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gin or source of the SEA was identifiable, such as infectious skin lesions, a genitourinary infectious process, a gastrointestinal focus, and oral lesions (Table 3). Because articles in the literature reported that comorbid and underlying conditions are significant factors associated with patient outcome, we assessed such factors in our patient population (Table 4). In concordance with reports in the literature, the most common comorbid condition was diabetes mellitus, found in 38 (35.8%) patients in our study. The next most common conditions were vascular disease (33 [31.1%]) patients, underlying renal insufficiency or receipt of dialysis (32 [30.2%]), sepsis and/or bacteremia (23 [21.7%]), and drug abuse (23 [21.7%]). Also seen in our patient population, but with lesser frequency, were underlying malignancy, receipt of immunosuppressive therapy, chronic inflammatory diseases, and endocarditis.

For each of the 106 patients, the causative organism was determined (Fig. 2). The most common causative organism was methicillin-sensitive *Staphylococcus aureus* (39.60%), followed by methicillin-resistant *S. aureus* (MRSA) (31.10%), *Streptococcus* spp. (6.60%), and coagulase-negative *Staphylococcus* spp. (3.80%). Also found in some patients were *Klebsiella* spp. (2.80%), *Candida* spp. (1.90%), *Escherichia coli* (1.90%), *Aspergillus* spp. (1.90%), and *Enterobacter* spp. (0.94%). Cultures were negative for 6 (5.6%) patients. In terms of imaging modalities used, MRI was used most frequently (81 patients [76.4%]), followed by CT-guided biopsy (15 [14.2%]), and CT (7 [6.6%]). Surgical exploration was also used for diagnosis in 3 (2.8%) patients.

With regard to treatments offered and chosen surgical procedures (Table 5), 63 (59.4%) patients were offered a combination of antibiotics and surgery. Of these patients, 2 (3.2%) died and 61 (96.8%) were ultimately discharged. Of the 33 (31.1%) patients offered antibiotics alone, 4 (12.1%) died and 29 (87.9%) were discharged. All surgical patients received drainage, decompression, and debridement, and some also underwent fusion, corpectomy, and/or discectomy. As outlined in Table 5, 19 (30.2%) patients underwent spinal fusion; 14 (22.2%) un-

TABLE 1: Frequency of common presenting signs and symptoms among 106 patients with SEA

Sign or Symptom	Frequency, No. (%) [*]
back pain	48 (47.1)
neck pain	8 (7.8)
acute	25 (24.5)
progressively worsening	23 (22.5)
fevers/chills	34 (33)
altered mental status/lethargy	13 (12.7)
focal neurological findings	48 (47.1)
paralysis/paresis in extremities	25 (24.5)
paresthesia/pain in extremities	23 (22.5)
nausea/vomiting	5 (4.9)
urinary/bowel symptoms	18 (17.6)

^{*} Some patients presented with more than 1 sign or symptom. Percentages calculated out of 102 patients with complete data.

TABLE 2: Location of SEA with regard to primary or secondary causes in 106 patients

Location	Frequency, No. (%)
primary	
cervical	15 (17.6)
thoracic	29 (34.1)
lumbar	40 (47.1)
sacral	1 (1.2)
total	85 (80.2)
secondary	
cervical	1 (4.7)
thoracic	4 (19.0)
lumbar	15 (71.4)
sacral	1 (4.7)
total	21 (19.8)
ventral [*]	47 (58.8)
dorsal [*]	30 (37.5)
lateral/circumferential	3 (3.8)

^{*} Ventral or dorsal location data were missing for 26 patients; percentages are based on 80 patients.

derwent discectomy; 9 (14.3%) underwent corpectomy; and 46 (73.0%) underwent decompressive laminectomy (with drainage and/or debridement) only.

To tangibly describe outcomes with regard to neurological function, we reported outcomes objectively, based on a previously reported objective score (Table 6).²⁵ Patients were placed accordingly into 1 of 5 categories at time of most recent follow-up examination: full recovery of neurological function (29 patients), able to ambulate independently and without sphincter disturbance (8 patients), able to ambulate with assistance only and possible associated sphincter disturbance (9 patients), paraplegic or minimal recovery but bedridden (10 patients), or expired (6 patients). These outcomes were recorded at mean $\pm$ SD follow-up time of 8.4 ± 26 weeks (range 0–192 weeks); most were obtained at discharge. The other patients were lost to follow-up or discharged to another facility; thus, their records could not be obtained and reported.

Literature Review

Most studies reviewed were institutional case series (Table 7). Almost all were retrospective studies.

Epidemiology. The incidence of SEA has been in-

TABLE 3: Identified infectious origin of SEA in 36 patients among a series of 106 patients

Origin	SEA No.	
	Primary	Secondary
skin lesion	9	5
oral lesion/focus	3	1
gastrointestinal focus	5	1
genitourinary focus	9	3

TABLE 4: Comorbid and underlying conditions in 106 SEA patients

Concurrent Condition	Frequency, No. (%) [*]
diabetes mellitus	38 (35.8)
vascular disease	33 (31.1)
renal insufficiency &/or dialysis	32 (30.2)
sepsis &/or bacteremia	23 (21.7)
substance abuse (alcohol, tobacco, intravenous drug abuse)	23 (21.7)
previous spine op	21 (19.8)
malignancy	14 (13.2)
immunosuppressive therapy &/or chronic inflammatory disease	11 (10.3)
endocarditis	2 (1.9)

^{*} Because some patients had more than 1 concurrent condition, percentages do not add up to 100.

creasing. Recent estimates are around 2–3 cases per 10,000 hospital admissions.^{1,11,37,46} Spinal epidural abscesses can be classified into primary versus secondary. Secondary SEAs occur in patients with a history of invasive spinal procedures.⁴⁶ Some have defined secondary SEA as being associated with vertebral osteomyelitis.²⁰ Most patients are in the 50- to 70-year age range; men are more likely to be afflicted.²³ Origins or foci of infection have been identified and include pathogens in skin, oral mucosa, genitourinary system, and bowel.⁴⁶ Frequently reported concurrent conditions are diabetes mellitus, previous spine surgery, intravenous drug abuse, epidural anesthesia, alcoholism, renal failure, hemodialysis, systemic chronic disorders, and immunosuppression.^{3,17,21,33,43} Factors that can be associated with a worse prognosis are older age, diabetes mellitus, neurological and mental deterioration, and dorsal location of the SEA.^{1,8,9,19,23,32} Additionally, higher reoperation and mortality rates are associated with renal failure and hemodialysis.^{44,45} In terms

FIG. 2. Percentage of microorganisms cultured among 106 patients with SEA. Coagulase-negative = coagulase-negative *Staphylococcus*; *E. coli* = *Escherichia coli*; MSSA = methicillin-sensitive *S. aureus*.

TABLE 5: Treatments and surgical procedures performed in SEA patients

Treatment	Frequency, No. (%) [*]
antibiotics alone	33 (31.1)
antibiotics + op	63 (59.4)
decompressive laminectomy only	46 (73.0)
fusion	19 (30.2)
discectomy	14 (22.2)
corpectomy	9 (14.3)

^{*} Because some patients received a combination of fusion, corpectomy, and/or discectomy, percentages do not add up to 100.

of pathogenic microorganisms, overwhelmingly the most common is *S. aureus*, followed by *Streptococcus* spp. and gram-negative bacteria.^{4,16,17,30,38} Mortality rates are 5%–23%;^{1,9,11,30} morbidity rates are 33%–47%.^{9,10}

Presentation and Diagnosis. The most common signs and symptoms are neck and back pain, fever, and neurological deficits.^{4,28} Others, such as altered mental status and incontinence, can also be present.^{4,28} However, presentation is variable and can be ambiguous, leading to delayed diagnosis.^{7,12,14,18,27,37,41} Reportedly, SEA usually occurs in the thoracolumbar spine, dorsally.^{19,30,31} In one study, systemic symptoms were more common among those with ventral lesions, and focal deficits were more common among those with dorsal lesions.¹⁹ In the absence of contraindications, the standard imaging modality is MRI; CT myelography is an equivalent option.^{10,33,41} Ultrasonography has been used intraoperatively to ensure complete abscess clearance.⁴² Along with increased white blood cell count, inflammatory markers such as C-reactive protein and erythrocyte sedimentation rate are usually also increased; both markers can be used to monitor treatment success^{10,12,18,43} and have also been found to predict treatment success and outcomes.^{32,38}

Treatment and Outcome. Generally, antibiotics should be initiated as soon as SEA diagnosis is suspected. For 25% of patients, antibiotic therapy for less than 4 weeks is associated with treatment failure.^{4,38} Therapy should be culture specific, and peripheral blood cultures can be possibly used as indicators of the pathogen.^{10,17,32} Computed to-

TABLE 6: Outcomes after treatment for 106 SEA patients

Outcome	Frequency, No.
full recovery; neurologically intact	29
independent ambulation; no sphincter disturbance	8
ambulation w/ assistance; possible sphincter disturbance	9
paraplegic or minimal recovery	10
died	6
lost to follow-up [*]	44

^{*} Includes patients who were discharged to an extended nursing care facility.

TABLE 7: Study methodology, treatment, and outcomes of select studies on SEA, 2002–2014*

Authors & Year	Type & Duration of Study	No. of Patients	Treatment (no. of patients)	Special Aspects	Outcomes†
Adogwa et al., 2014	retrospective, 14 yrs	82	op + antibiotics (30) w/o op (52)	all patients >50 yrs	good: 12 (15%), 7 underwent op unchanged: 41 (50%), 10 underwent op death: 20 (25%), 9 underwent op medical management failed & op required: 41%
Patel et al., 2014	retrospective, 6 yrs	128	antibiotics alone (51) op (77)	NA	
Kim et al., 2013	retrospective, case controlled, 18 yrs	355	op (214) nonop (142)	largest study in the literature	nonop management failed: 54/142; risk factors for failure: age >65 yrs, diabetes, MRSA
Connor et al., 2013	retrospective, 11 yrs	77	op (57) nonop (20)	NA	operative w/ significant improvement: 78.2% nonoperative w/ significant improvement: 82.4%
Chen et al., 2011	retrospective, 6 yrs	45	antibiotics (19) antibiotics + op (26)	used the Barthel Index	good prognosis: 28 poor prognosis: 17
Huang et al., 2012	retrospective, 5 yrs	29	antibiotics + op (16) antibiotics (29)	used the Barthel Index	good prognosis: 21 poor prognosis: 8
Oktenoglu et al., 2011	retrospective, 13 yrs	14	op (12) drainage of abscess (1) CT-guided biopsy (1)	not applicable	full recovery: 7 improvement: 4 no change: 1
Wu et al., 2011	retrospective, 4 yrs	41	antibiotics antibiotics + op group I: w/ ESRD (12) group II: w/o ESRD (29)	comparison study of patients w/ & w/o ESRD	mortality rates Group I: (11.1%) Group II: (6.9%) prognosis same for patients w/ and w/o ESRD
Zimmerer et al., 2011	prospective observational, 4 yrs	36	surgical removal of abscess + decompression (34) antibiotics (36)	dental examinations conducted for all patients	full recovery: 22 (61%) neurological function better than at admission: 34 (100%)
Wong et al., 2011	retrospective, 6 yrs	19	10/19 = op (10, decompression & laminectomy [8], discectomy [2]) percutaneous drainage (2)	largest literature review of SEA in ESRD patients	all-cause mortality rate: 25%
Huang et al., 2011	retrospective, 6 yrs	12	not specified: medical (antibiotics) &/or surgical	gram-negative bacterial SEAs	mortality rate: 16.7%
Wang et al., 2010	retrospective, 7 yrs	41	antibiotics + op (39) antibiotics (2)	excluded patients w/ Hx of spine op, spinal anesthesia, TB, or trauma	mortality rate: 5%
Koo et al., 2009	case-control review, 5 yrs	29	observation of AIS motor score improvement (SEA vs traumatic SCI)	rehabilitation outcomes study	motor recovery better for SEA patients than for traumatic SCI patients
Karikari et al., 2009	retrospective, 10 yrs	104	CT-guided aspiration or blood culture + antibiotics (64) surgical decompression (40)	ventral or dorsal SEA should be considered when deciding on treatment plan	no significant difference in outcome in the 2 treatment groups
Boström et al., 2008	retrospective, 15 yrs	46	antibiotics + op (37) CT-guided drainage (9)	used Frankel grading system	mortality rate: 6.5%

(continued)

TABLE 7: Study methodology, treatment, and outcomes of select studies on SEA, 2002–2014* (continued)

Authors & Year	Type & Duration of Study	No. of Patients	Treatment (no. of patients)	Special Aspects	Outcomes†
McKinley et al., 2008	retrospective, 10 yrs	34	comparison of outcomes after infection-related SCI vs traumatic SCI	rehabilitation outcomes study	acute-care stays longer & discharge to home less often for patients w/ infection-related SCI than w/ traumatic SCI
Savage et al., 2005	retrospective, 10 yrs	52	antibiotics (29) surgery + antibiotics (23)	medical Rx failed more often for thoracic SEAs	excellent outcome for medically treated group: 83%)
Kumar & Hunter, 2005	retrospective, 5 yrs	20	antibiotics + surgery (18) antibiotics (2)	outcome scores assigned on a scale of 1 to 5	good: 15/20 poor: 5/20
Chen et al., 2004	retrospective, 7 yrs	17	antibiotics + surgery (17)	9 of 17 SEAs were caused by spinal procedures	good: 53% fair: 18% poor: 29%
Siddiq et al., 2004	retrospective analysis, 14 yrs	57	antibiotics (25) antibiotics + CT-guided aspiration (7) surgery (28)	NA	clinical outcomes comparable for antibiotics alone or antibiotics + CT-guided drainage compared w/ op
Löhr et al., 2005	retrospective review, 10 yrs	27	interlaminar approach (14) laminectomy (13)	used intraop ultrasonography	no deficit: 9 ambulatory w/ deficit: 12 nonambulatory w/ deficit: 1 paraplegic: 4
Davis et al., 2004	retrospective case-control study, 10 yrs	63	SEA (63) vs 126 controls w/ spine pain	emergency department study	in emergency department, ESR can be potential screening tool before MRI
Curry et al., 2005	retrospective review, 6 yrs	48	antibiotics initially (11 then required op after decompensating): 23 surgery: 25	presentation/rationale given for 11 patients initially treated conservatively	outcomes worse after conservative Rx w/ antibiotics alone compared w/ early op
Joshi et al., 2003	retrospective review, 10 yrs	39	surgical decompression (39, 13 of which required stabilization)	outcomes measured after 1 yr	no or minimal paresis: 51% severe paresis or paraplegia w/o incontinence: 23% incontinence: 18% death: 8%
Tang et al., 2002	retrospective review, 10 yrs	46	posterior decompression & drainage (25) antibiotics (21)	thrombocytopenia may be a risk factor for a poor outcome	accurate initial SEA Dx rate: only 26%
Soehle & Wal-lentfang, 2002	retrospective review, 7 yrs	25	op (25, 23 patients treated w/in 24 hrs after admission)	WBC and CRP levels were prognostic for outcomes	mortality rate: 20%

* AIS = American Spinal Injury Association Impairment Scale; CRP = C-reactive protein; Dx = diagnosis; ESR = erythrocyte sedimentation rate; ESRD = end-stage renal disease; Hx = history; NA = not applicable; Rx = medical treatment; SCI = spinal cord injury; TB = tuberculosis; WBC = white blood cell count.

† Data expressed as number or percentage of patients unless otherwise indicated.

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mography-guided percutaneous aspiration can be both diagnostic and therapeutic.⁹ In previous years, surgical intervention was the mainstay of management of this infection process, particularly when symptoms had not been present for longer than 36–72 hours.^{1,9,19,23,31,39} Later studies have shown successful outcomes with medical management alone.^{6,19,36,37} However, other more recent studies have indicated that early surgery has better outcomes.^{9,26,32,33} Others have demonstrated that medical treatment alone is more likely to fail among elderly patients or those with diabetes mellitus and/or MRSA infection.²³ The operative approach should be guided by the spatial orientation of the abscess.¹⁹ Instrumentation and fusion are usually avoided but might be required in rare cases.^{19,31} Outcomes are mostly reported objectively, and obtaining long-term follow-up information for all patients can be difficult (Table 7). A few studies reporting long-term rehabilitative outcomes showed contradictory results.^{24,29}

Discussion

It is widely acknowledged that diagnosis and treatment of SEAs should be conducted as soon as possible because of their potentially devastating neurological sequelae. Regarding diagnosis, the literature describes the most common presenting complaints as neck and back pain, but other reported signs and symptoms are neurological deficits, fever, altered mental status, and incontinence.^{4,10,19} Our study confirms all signs and symptoms described in the literature; back pain and neurological deficits (or both) were most common among patients in our study (experienced by almost half of patients).

Because of the nonspecific findings for SEA, a high index of suspicion is essential for patients with such symptoms.^{17,21} Such suspicion, along with early neuroimaging studies, is crucial for diagnosis and management.¹⁷ Certain predisposing conditions can further increase clinical suspicion. The literature cites the most common predisposing factor as being diabetes mellitus, along with previous spinal intervention, intravenous drug abuse, alcoholism, renal failure, bacteremia, and chronic inflammatory conditions.^{17,33} The patient data from our study parallel these findings. Epidural anesthesia has a well-established association with SEA (responsible for around 5% of all SEAs).^{3,5,21} A reported source of bacteremia and sepsis that can lead to development of SEAs is vascular access-related infection, notably in hemodialysis patients.^{38,41} Clinicians should look for potential infectious origins such skin, oral, genitourinary, and/or gastrointestinal infections that can lead to bacteremia and a resulting SEA, as demonstrated by more than a third of the patients in our study.

Oktenoglu et al. reported that the most common location for SEAs was the thoracolumbar region.³¹ Our results build on this; in our study, the most common location for primary and secondary SEAs was the lumbar spine, followed by the thoracic spine. The mean number of vertebral levels spanned by the SEA was approximately 2 for both forms, with no significant difference. According to our literature search, Oktenoglu et al. were also the first to note that the location was dorsal in almost two-thirds of

patients; they attributed this finding to hematogenous or contiguous spread from a paravertebral infection as well as the larger epidural space and venous plexus in this segment of the spine.^{2,31} Ventrally located SEAs are thought to be more rare and are usually associated with spondylitis or diskitis, although in that small retrospective study of 14 patients, the location was dorsal in only 6 patients. Patient data from our series revealed a prevalence of ventral SEAs (47 patients); SEAs were dorsal for only 30 patients (Table 2). These findings may be the result of a relatively high prevalence of osteomyelitis and diskitis in the studied population.

As has been found in other studies, *S. aureus* was the most common pathogen among patients in our study. A total of 75 (70.0%) patients with SEAs had *S. aureus* infection, followed much further by *Streptococcus* spp. infection. Our data support the recommendation that antibiotic therapy including an antistaphylococcal agent should be initiated as soon as SEAs are diagnosed and then should be adjusted according to culture results.^{4,38} Although the period of antibiotic treatment is debatable, therapy should last longer than 4 weeks because therapy for less than 4 weeks is associated with a 25% rate of relapse.^{4,15,38} The neuroimaging study of choice is MRI because it provides the ability to visualize soft tissues as effectively as CT myelography with a comparable sensitivity for SEA (91%–92%); it offers the advantages of superior identification of perimedullary lesions and does not pose the risk of introducing pathogens into the thecal sac.⁴¹ MRI helps distinguish SEAs from other conditions in the differential diagnosis, which include tumor and subdural abscess.²² A characteristic description of an SEA on MR images includes a collection in the epidural space that is isointense or hyperintense on T1 images that enhances with gadolinium contrast and a T2 image with nonhomogeneous and hyperintense signal.³³ A study by Tung et al. found that a poor outcome and/or lack of recovery to normal was associated with 50% narrowing of the spinal canal on initial MR images ($p = 0.03$), peripheral contrast enhancement ($p = 0.05$), abnormal cord signal intensity, and an abscess longer than 3 cm ($p = 0.01$).⁴¹ In patients for whom MRI is contraindicated, other diagnostic modalities can be used, such as CT scanning, CT-guided biopsy, and surgical exploration when none of the less invasive strategies are conclusive.

Surgical decompression has been suggested as the mainstay of therapy because symptoms result mainly from direct constriction of neural elements or the resultant ischemia.^{2,10,13,33,42} Most authors suggest that the upper time limit for consideration to intervene surgically is 36–72 hours from onset of neurological sequelae.^{1,9,19,23,32,36,39} Although for select patients a conservative approach of antibiotics alone might be appropriate,^{11,36,37} in our study, patients with focal neurological signs or symptoms were offered immediate surgical intervention. Those who had no response to antibiotics (as deemed by follow-up MRI) were also surgical candidates. Among those who received surgery along with antibiotics, 3.2% died; among those who received antibiotics alone, 12.1% died, suggesting a potential mortality rate reduction with an aggressive surgical treatment approach. Nonetheless, such a finding

needs to be further verified with future evidence through much larger studies.

In a larger study by Karikari et al., the operative approach was guided by the location of neural tissue compression.¹⁹ Dorsal SEAs were treated with posterior decompressive laminectomy with or without fusion. Ventral SEAs, particularly ventral cervical SEAs typically occurring in association with osteomyelitis or diskitis, were more likely to be treated by using an anterior approach because it allowed more thorough debridement and facilitated reconstruction of the anterior column.^{19,22,35} When an abscess was located dorsally, the treatment of choice was laminectomy, which has been identified as the most common procedure for thoracolumbar SEAs.²² These reported treatment approaches are similar to those used for the 106 patients in our study.

According to the literature, when dealing with an infected surgical site, spinal instrumentation is contraindicated because of increased risk for infection; however, spinal instrumentation might be necessary when extra support is needed for stabilization or when spinal stability is compromised from decompression.^{31,35} In the Oktenoglu et al. study,³¹ metallic instrumentation was applied to 5 of 14 patients; the SEA was successfully treated for 4 of these patients. In our cohort, among the 19 patients who underwent fusion, the SEA was more likely to be ventral (12 [63.2%]) and/or thoracic (10 [52.6%]). Additionally, outcome was good for less than one-third of the patients (6 [31.6%]). Only 1 patient experienced SEA recurrence; however, obtaining long-term results with regard to reinfections and rehospitalizations in our patient population was difficult because many patients were lost to follow-up or received follow-up care at other institutions.

In our study, patient outcomes were based on long-standing neurological deficits and overall functional capacity. We reported outcomes objectively, in a manner similar to that described previously,²⁵ which was suitable for the retrospective nature of our analysis. Of the patients not lost to follow-up, the frequency of good outcomes (full recovery, independent ambulation, no sphincter disturbance) was 37 (60.7%); the rest of the patients (39.3%) were determined to have poor outcomes (assisted ambulation, sphincter disturbance, paraplegia, bed confinement, or death).

Literature Review

Our goal for the literature review was to update current knowledge on nontuberculous bacterial SEAs. Particular attention was paid to the medical and surgical management of this condition, which is increasingly encountered by spine surgeons. Most of the studies reviewed were small, retrospective, single-center studies (Table 7). To the best of our knowledge, at the present time there is no consensus or guidelines for the treatment of SEAs. Clinical recommendations are based mostly on results of these studies and on expert opinions.

The most recent study reported results for elderly patients (> 50 years of age).¹ Most (> 85%) of their cohort had either an unchanged condition or a poor outcome. The authors reported that for this age group, early surgical intervention lacked advantage compared with use

of antibiotics alone. Although another very recent series showed that ideal treatment included surgery for those with focal deficits, age remains a factor; outcomes are better for younger patients.⁹ Yet another article recommends close attentiveness for those with nonoperative treatment because it is associated with a high rate of failure (> 40%). In the largest series reviewed (355 patients), Kim et al. showed that medical treatment is likely to fail for those older than 65 years of age and for those with MRSA infection, diabetes mellitus, and/or neurological symptoms.²³ On the basis of these findings, the authors provide a simple algorithm for determining the likelihood of failed medical management. The latter 2 studies reported high concordance between blood and abscess cultures, enabling clinicians to tailor antibiotics to blood culture results.^{9,23}

In 2011, Chen et al. conducted a 6-year retrospective review of 45 patients treated either with antibiotics alone or with antibiotics and surgery.⁸ They noted that the prognosis was worse for patients who at the time of initial presentation had diabetes mellitus, heart disease, higher age, and/or altered mental status. Outcomes were also poorer for those with late-stage disease, defined by the authors as neurological sequelae such as sensory impairment, weakness, bladder or bowel dysfunction, and/or paralysis. Huang et al. reported isolation of *S. aureus* from 29 (69%) of 42 patients and gram-negative bacteria from 12 (28.5%) of 42.¹⁶ This finding is consistent with findings previously reported in the literature and also with our finding that *S. aureus* is the most commonly isolated bacterium. Another study noted similar culprit microorganisms and reiterated that MRI should be performed for patients with back pain and fever, especially those with risk factors for a compromised immune system.¹⁷

Wu et al. compared outcomes for patients with and without end-stage renal disease.⁴⁵ An attending neurosurgeon decided whether to treat with antibiotics alone or with antibiotics and surgical decompression. The prognosis remained unchanged for patients with and without end-stage renal disease; however, in this patient population for whom infectious complications were a leading cause for illness and death, end-stage renal disease was a risk factor for repeat surgery. Wong et al. published similar results for a larger study in which mortality rate was higher among hemodialysis patients and likelihood for neurological improvement after medical or surgical intervention was decreased.⁴⁴ In our study, 10 (9.3%) SEA patients were receiving hemodialysis at the time of diagnosis. Of the 6 patients who died, 2 had received hemodialysis, adding to the many factors to be considered for SEA patients.

In a 4-year prospective observational study, of 36 patients, Zimmerer et al. described 34 who had undergone surgical SEA removal plus decompression followed by long-term antibiotic administration.⁴⁶ This study was unique because all patients underwent clinical dental examinations with CT. Of the 36 patients, 22% had oral pathogenic bacteria. In 2010, Wang et al.⁴³ conducted a 7-year retrospective study and discovered that poor motor recovery is correlated with poor glycemic control, prolonged muscle weakness before initiation of treatment, and poor response to treatment as measured by trends in

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white blood cell counts and C-reactive protein levels. In a larger study, Karikari et al. noted no significant difference in outcomes between 2 treatment groups: CT-guided aspiration plus antibiotics versus surgical decompression.¹⁹ They highlighted the importance of abscess location with regard to decision making. They found that patients with ventral SEA were more likely to show systemic signs and symptoms such as fever before neurological deficits and back pain (because of associated diskitis or osteomyelitis) and that patients with dorsal SEA were more likely to show neurological deficits. The former group can be treated conservatively with antibiotics and CT-guided aspiration, primarily because of early detection and significantly smaller SEAs.

In a series of 27 patients treated operatively, Löhr et al.²⁶ demonstrated a strong advantage of surgical management. They advocated for an interlaminar decompressive approach, which provided more postoperative spinal stability and a similar likelihood of reoperation for recurrent or residual abscess when compared with laminectomy. In addition, they found that intraoperative ultrasonography enabled visualization of abscesses that might be hidden, thereby helping to reduce the likelihood of recurrence. A 10-year retrospective study noted excellent outcomes for 83% of medically treated patients.³⁶ Selection criteria for the medically treated group included normal or stable neurological examination for more than 72 hours before admission (including signs and symptoms of radiculopathy or cord compression). Soehle and Wallenfäng³⁸ analyzed outcomes of 25 surgical patients after an average of 11 months. They found that poor outcomes were associated with higher preoperative and postoperative white blood cell counts ($> 14,000$ cells/ μ l), higher postoperative levels of C-reactive protein, a cervicothoracic location of the SEA, and lower limb deficits at the time of initial examination.

Studies have shown that misdiagnosis is common and can occur for up to 74% of patients, which leads to poorer outcomes.^{7,37} Chen et al. identified 3 of 17 patients with thoracic SEA who complained of abdominal symptoms, which led to misdiagnosis; they concluded that abdominal symptoms can mask neurological deficits and lead to delayed diagnosis.⁷ After a 10-year study, in 2003, Joshi et al.¹⁸ concluded that fever is not mandatory for the diagnosis of SEA. Because typically the first symptom of SEA is back pain, laboratory studies including erythrocyte sedimentation rate and C-reactive protein levels should be obtained. If those values are elevated, urgent MRI would help with early diagnosis of SEA. A later study builds on this finding, reporting that body temperature and white blood cell count within reference ranges do not preclude a diagnosis of SEA.¹⁰ Davis et al.¹² reemphasize that erythrocyte sedimentation rate could be a potential screening tool before obtaining MRI for patients in the emergency room with suspected SEA.

Very few study reports comment on functional outcomes of SEA patients. Koo et al.²⁴ studied neurological outcomes among patients with SEA-related myelopathy after an inpatient rehabilitation program and compared them with outcomes among patients with traumatic spinal cord injury. According to the American Spinal Injury

Association (ASIA) Impairment Scale scores, patients with SEA-related neurological deficits including complete motor or sensory loss showed significant improvement compared with patients with traumatic spinal cord injury. Overall, 73% of patients with SEA compared with only 9% of patients with traumatic spinal cord injury converted from complete ASIA Impairment Scale Grade A to incomplete ASIA Impairment Scale Grade B, C, or D. McKinley et al.²⁹ compared outcomes of patients with traumatic spinal cord injury to outcomes of those with spinal infections; 85% of those patients with infections had SEAs. Patients with infections stayed in acute care significantly longer than did those with traumatic spinal cord injury; however, the length of stay in rehabilitation did not differ significantly between the 2 groups. In addition, among patients in the infections group, motor score improvements were lower and patients were less often discharged home than were those with traumatic spinal cord injury, reinforcing the importance of early patient and family education regarding potential future outcomes.

Clinical Decision Making

On the basis of our experience and on previous evidence from the literature, we present an algorithm for diagnosis and treatment of SEA (Fig. 3). Patients with suspicious signs and symptoms should undergo appropriate blood testing (e.g., white blood cell counts, erythrocyte sedimentation rates, C-reactive protein levels, cultures) and MRI; those with nonremarkable negative MRI findings should receive conservative treatment and monitoring. If imaging is suggestive of SEA, the decision for operative management should be based on the presence of factors that are highly associated with failure of medical treatment alone (i.e., diabetes mellitus, age > 65 years, neurological deficits [for < 36 –72 hours], and MRSA-positive blood culture results). Otherwise, medical treatment with antibiotics only can be confidently started. These patients should undergo CT-guided biopsy of the lesion, especially if blood cultures are inconclusive. They also need to be monitored for signs of medical treatment failure, such as onset of neurological compromise and persistence of elevated inflammatory markers (C-reactive protein levels, white blood cell count), blood culture positivity, and imaging indications of SEA. If signs of medical failure are detected, surgical decompression should be initiated promptly.

Limitations

A limitation encountered in our analysis and in published SEA studies was lack of complete long-term follow-up data. After discharge, a number of patients were transferred to other facilities. These limitations impede the ability to obtain coherent assumptions on outcomes of each treatment modality. In addition, the retrospective nature of these studies further limits their interpretation. Errors in the data and in data collection can and do occur. As best we can determine, advances in imaging modalities and treatment strategies have decreased deaths from this serious infection. As such enhancements continue to expand, future multicenter studies with complete long-term follow-up can augment our understanding of the condition.

Fig. 3. Algorithm for diagnosis and treatment of SEA. CRP = C-reactive protein levels; DM = diabetes mellitus; neuro = neurological; WBC = white blood cell count.

Conclusions

Prompt diagnosis and treatment of bacterial SEA can improve outcomes, but the outcome will be poor for a substantial percentage of patients. Those with multiple risk factors—older age, diabetes mellitus, end-stage renal disease, and intravenous drug abuse—are predisposed to this rare infection and to having worse outcomes. The organism most frequently responsible for SEA is *S. aureus* and MRSA has been correlated with a higher rate of treatment failure. Optimum care involves diagnosis with MRI, administration of appropriate antibiotics with or without surgery, and appreciation of the effects of concurrent conditions and risk factors. After the decision to operate has been made, surgery should be performed immediately and no longer than 36–72 hours after onset of neurological symptoms. Although management with surgical decompression was associated with lower mortality rates in our study and better outcomes in studies reported in the literature, multiple studies also support use of antibiotic therapy alone. Undoubtedly, neurological status at the time of presentation is a key factor in decision making and patient outcome. Overall, management decisions entail individual patient considerations. Although this aspect of the condition is a challenge for spine surgeons, an evidence-based algorithm is proposed. We hope that it will be a valuable tool for clinicians. Future large studies with long-term follow-up can verify the utility of this algorithm and can establish a consensus-based protocol for this increasingly prevalent condition.

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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