

# Spinal Epidural Abscess: A Review of Presentation, Management, and Medicolegal Implications

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Spinal epidural abscess (SEA) is a rare condition associated with significant morbidity and mortality. Despite advances in diagnostic medicine, early recognition of SEAs remains elusive. The vague presentation of the disease, coupled with its numerous risk factors, the diagnostic requirement for obtaining advanced imaging, and the necessity of specialized care constitute extraordinary challenges to both diagnosis and treatment of SEA. Once diagnosed, SEAs require urgent or emergent medical and/or surgical management. As SEAs are a relatively rare pathology, high-quality data are limited and there is no consensus on their optimal management. This paper focuses on presenting the treatment modalities that have been successful in the management of SEAs and providing a critical assessment of how specific SEA characteristics may render one infection more amenable to primary surgical or medical interventions. This paper reviews the relevant history, epidemiology, clinical presentation, radiology, microbiology, and treatment of SEAs and concludes by addressing the medicolegal implications of delayed treatment of the disease.

**Keywords:** Spinal epidural abscess; Infections; Spine

## Introduction

Spinal epidural abscess (SEA) was described by Giovanni Morgagni in 1761, and the first surgical intervention to address an SEA, although unsuccessful, was performed by Johann Barth in 1901 [1,2]. Successful operative interventions were performed for SEAs in the 1930s and 1940s as documented by Craig and his colleagues [3]. Historically, the incidence of SEAs has been reported at approximately 0.2–2.0 cases per 10,000 hospital admissions [4]. Over

the past several decades, the reported incidence of SEAs has escalated between two- and six-fold [1,5-7]. Current prevalence estimates range between 2.2 and 20 cases per 10,000 hospital admissions, with the majority of estimates projecting 2–8 cases per 10,000 hospital admissions [7-13].

Before the advent of advanced imaging, SEA was a difficult diagnosis to substantiate, and before the introduction of advanced surgical techniques and antibiotic therapy, SEAs were almost uniformly fatal. The mortality rate currently reported in patients with SEAs is between 1.3%

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and 31% [1,4,8,14-17]. In a large meta-analysis of patients with SEAs published 2 decades ago, Reihnsaus et al. [3] reported an overall mortality rate of 16%. More recent estimates, including a 2018 review of 1,094 patients with SEAs, reported adjusted mortality rates of 3.7%–5% [6,18]. However, more than one-third of SEA survivors have poor neurological outcomes [19-21].

The classic clinical presentation of SEA was described as a triad of (1) pyrexia, (2) neck or back pain, and (3) neurological deficit. Even in the era of advanced imaging, it is important to maintain a high index of suspicion for SEA, as only 8%–15% of patients present with this triad [4,6,22-25]. The specificity of these clinical indicators is low [26], as one-third of patients present with isolated back pain [27] and only two-thirds of patients report symptoms in addition to back pain [28]. Fever may be noted in only one-fourth of patients [8].

Due to the vague presentation, patients are often examined by multiple physicians before making a diagnosis [1,19,22]. Prolonged delays in the diagnosis of SEA are common and occur in up to 89% of cases [1,19,22]. Timely diagnosis of SEA is paramount, as the neurological status on presentation is the single most important predictor of outcome [5,29]. To prevent irreversible neurological damage, early decompression within 24–36 hours of the onset of the deficit is recommended [16,20,30].

### Spread of Disease

Pathogens invade the epidural space through the following three primary mechanisms: (1) hematogenous dissemination from a distal site, (2) extension from contiguous infected tissues, and (3) direct external inoculation [1,6,19,26]. The most common proposed mechanism of non-iatrogenic SEA is hematogenous dissemination, which has been purported to account for 50% of cases [6]. Of these cases, the most common proposed nidus of infection is the skin, and less commonly, the respiratory system, the urogenital system, and the oral cavity are also implicated [6]. Cervical SEA is more common in patients with intravenous drug use (IVDU) who inject them into the upper extremity and neck [17,19,31]. Lumbar involvement may be more common in those who inject the drugs into the legs or the groin [9,17,19].

Infections in the spine are often spread through the vertebral venous plexus (VVP), which is commonly referred to as the Batson plexus, named after Dr. Oscar V. Batson

who described the functional anatomy of the VVP in 1940 [32]. The VVP is directly connected to the venous system of the brain and acts as a reservoir with an important role in regulating intracranial pressures [32,33]. To this end, the VVP has no valves to facilitate bidirectional flow [33]. The VVP has numerous connections to the veins of the thoracoabdominal wall, the veins of the back, as well as the pulmonary, caval, and azygos systems [33,34]. In addition, the VVP has connections to the prostate, sacral, and pelvic plexuses [34]. Provided that the VVP has a rich system of interconnections throughout the body, and is a low flow/low pressure system, several SEAs can be attributed to hematogenous spread through the VVP system. Moreover, the VVP is a route for tumor dissemination, air, and cement embolism [32].

Contiguous extension from a nearby infection is responsible for approximately 30% of SEA cases, and the remainder of cases are attributable to direct inoculation during surgery and from instrumentation or procedural events [19,35-39]. Chan and Dasey [40] estimated that surgical procedures with spinal instrumentation account for 5.5% of SEAs. Other authors have reported estimates of 1.1%–15% [1,41]. Zimmerer et al. [41] reviewed 36 cases of SEA at a tertiary referral center where 20 of 36 patients (56%) had SEAs secondary to either elective spinal injections (four patients) or surgery (16 patients). However, the incidence of SEAs following spinal or epidural anesthesia is extremely rare and has been reported in approximately 0.0002% of procedures [40].

### Predisposing Factors

There are several factors that predispose to SEAs. The literature has reported extensively on the most relevant risk factors and comorbidities associated with SEAs (Table 1). IVDU is a common risk factor associated with SEAs, with up to 53% of cases having some association [2,3,14,19,23,28,42,43]. Other relevant risk factors include alcoholism, reported at 1.8%–22% [2,3,14,19,23,28,42,43], and human immunodeficiency virus infection, reported at 1.6%–21.7% [2,14,19,23]. Diabetes mellitus may be the most relevant risk factor in patients who do not engage in high-risk behaviors and has been reported in approximately 21%–42.9% of cases [2,3,14,19,23,28,29,42,43]. Other common medical conditions associated with SEAs include morbid obesity [2], malignancy [2,3,23,43], long-term corticosteroid use [2],

**Table 1.** Co-morbidities associated with spinal epidural abscess

Author	Type of study	No. of patients	DM (%)	Immuno-compromised (%)	Malignancy (%)	ESRD (%)	HIV (%)	IVDA (%)	Alcohol (%)	BMI >35 kg/m <sup>2</sup>	Distal infection (%)
Alton et al. [68] (2015)	Single institutional retrospective review-cervical SEA only (7 yr)	62	21	-	-	6.5	-	53.2	-	3.2	-
Arko et al. [28] (2014)	PubMed search (15 yr)	429	26.9	-	-	12.0 <sup>a)</sup>	-	21.6	13.1	-	-
Artenstein et al. [7] (2016)	10-yr. retrospective, tertiary-care, regional, academic medical center	162	30.4	6.8	-	6.0	1.6	14.8	15.2	-	17.2
Connor et al. [16] (2013)	Retrospective review of patient charts (11 yr)	77	26.3	-	-	12.3	1.8	19.3	1.8	-	38.6
Ju et al. [103] (2015)	Single institutional retrospective review non-contiguous abscess (18 yr)	233	25.8	16.7	-	-	-	18.5	17.6	-	-
Karikari et al. [42] (2009)	Retrospective, single institution (10 yr)	104	33.6	9.6	-	19.2	-	1.92	4.8 <sup>b)</sup>	-	10.6 <sup>d)</sup>
Kim et al. [72] (2014)	Single institutional retrospective review (18 yr)	355	26	15	16	-	-	20	22	-	-
Ma et al. [48] (2012)	Retrospective, single institution (24 yr)	35	3	3	-	-	-	-	-	-	-
Shah et al. [44] (2018)	Single institutional retrospective review	1,053	23	14	7.5	4.2	2.0	18	17	13 (>30 kg/m <sup>2</sup> )	29.2
Shweikeh et al. [47] (2017)	Retrospective, single institution	106	35.8	-	13.2	30.2	21.7	-	-	-	-
Spernovasilis et al. [71] (2017)	Retrospective, single institution (medical treatment only)	21	42.9	23.8	-	-	-	23.8	-	-	-
Suppiah et al. [66] (2016)	PubMed review (25 yr)	1,843	27.6	11.2	12.2	13.2 <sup>d)</sup>	-	23.2	15.1	-	30.6 <sup>e)</sup>
Vakilii et al. [8] (2017)	Single institutional retrospective review non-contiguous abscess (10 yr)	101	26.7	-	3.0	4.0	5.0	-	-	-	-
Zhu et al. [9] (2014)	Retrospective, single institution; all history of intravenous drug use (8 yr)	102	7	-	2	3	-	100	12	-	9.8

DM, diabetes mellitus; ESRD, end-stage renal disease; HIV, human immunodeficiency virus; IVDA, intravenous drug abuse; BMI, body mass index (kg/m<sup>2</sup>); SEA, spinal epidural abscess.

The specific listing of co-morbidities in the literature cited: <sup>a)</sup>Renal. <sup>b)</sup>Alcoholic or viral cirrhosis included. <sup>c)</sup>Endocarditis only distal infection included. <sup>d)</sup>Chronic kidney disease. <sup>e)</sup>Other sources and endocarditis combined.

pregnancy [3,23], and trauma (10%–12%) [3,19,23,28]. Chronic end-stage organ dysfunctions such as end-stage renal disease [2,3,14,19,23,29,42,43], liver disease, and cirrhosis [28,29,42] are strongly associated with SEA. Sepsis [2], distant site infection (including endocarditis) [2,3,23,42], indwelling catheter [2], and invasive spinal procedures [2,3,19] have also been implicated in SEA cases. Some authors report that no predisposing conditions can be identified in 20%–50% of cases [2,19].

### Microbiological Specification

The species isolated from tissue or blood culture in SEA cases is most often monobacterial (95%); however, polymicrobial infection has also been reported in 0%–10.6% of patients [8,29,44]. *Staphylococcus aureus* was the most common isolate found in 50%–93% of cases [3,8,28,42,45,46]. Although some studies report low ratios of methicillin-sensitive *Staphylococcus aureus* (MSSA) to methicillin-resistant *Staphylococcus aureus* (MRSA) at  $\leq 1.4$  [8,9,28], others report a higher prevalence of methicillin-resistant species [16,31,42,46–48]. In a retrospective review of patients with SEAs who underwent surgery, the most commonly identified microorganism was MRSA, followed by MSSA, in 43.2% and 23.7% of cases, respectively [49]. The presence of methicillin-resistant species in patients with SEAs portends a far worse prognosis than that in patients with methicillin-sensitive strains [46].

The second and third most common isolates are streptococcus species (6%–15%) [28,44] and Gram-negative organisms (4.8%–18.75%) [9,28,29,50]. Gram-negative organisms may be more commonly isolated from patients who use recreational intravenous drugs [51]. In an older series of 64 cases of IVDU, *Pseudomonas* species was isolated from 66% of patients [52]; however, this was not a common isolate in non-IVDU cohorts (0%–4%) [9,31,42].

This review largely focuses on the most common bacterial culprits responsible for causing SEAs. Nevertheless, less common bacterial, fungal, and parasitic pathogens responsible for causing SEAs do exist. Any pathogen that incites a pyogenic reaction in the confined space of the spinal cord can exert a mass effect and result in neurological injury. Tuberculosis is caused by a bacterial pathogen that may result in SEAs, especially in developing countries. In cases of SEA secondary to tuberculosis, the abscess is commonly associated with tuberculous spondylitis, which is commonly referred to as Pott's disease

[53]. The mainstay of treatment includes multiagent antitubercular therapy in addition to decompression of any compressed neural elements and correction of deformity caused by the disease. Multiagent therapy typically consists of a combination of rifampin, isoniazid, ethambutol, and pyrazinamide for 2 months, followed by an additional 9–18 months of rifampin and isoniazid. Medical treatment can be further tailored to the specific sensitivities of the isolated tubercular strain.

Fungal sources have also been implicated in SEAs. In a recent review of 1,053 cases of SEA from a single institution over a period of 23 years, nine of the 1,053 patients were found to have fungal culture isolates [54]. Seven of these patients were found to have *Candida* species, and two had *Aspergillus* species [54]. Patients with fungal-derived SEAs referenced in this paper were treated with antifungal agents for a minimum of 6 weeks up to 1 year unless they succumbed to their illness earlier [54]. Parasites can also be responsible for causing SEAs by inducing a local pyogenic reaction resulting in cord compression. Gopal et al. [55] reported on their case of vertebral hydatidosis causing cord compression and described the treatment, including decompression with complete cyst resection and antiparasitic agents for a minimum of 3 months. Other authors have reported about spinal hydatid and non-hydatid infections and have advocated treatment with decompression and a prolonged course of antiparasitic agents [56].

Although isolating the culprit microorganism allows for targeted antibiotic therapy, in 3.5%–60% of cases, no organisms are isolated from blood or tissue cultures [8–10,16,28,31,44]. Although it is unclear whether antibiotic administration before culture affects the probability of a positive culture, some authors recommend holding antibiotics until local cultures are taken to increase the probability of a targeted treatment, unless the patient is septic [16]. Cultures from the site of infection (78.1%–90%) are more often successful in isolating a pathogen than blood cultures (54.9%–60%) [16,42,57]. It has been reported that blood cultures correlate well with tissue cultures, and targeted antibiotic therapy may be initiated based on positive blood cultures [57]. Therefore, it may be prudent to use computed tomography (CT)-guided biopsy to obtain tissue culture in patients being managed medically to optimize antibiotic therapy [26,42]. Table 2 lists the microbiology of SEAs reported in the literature.

Table 2. Microbiology

Study	<i>Staphylococcus aureus</i>	MSSA	MRSA	Coagulase-negative <i>Staphylococcus</i> (such as epidermidis)	<i>Streptococcus</i> species	Gram-negative bacteria	Polymicrobial	None isolated	Other	<i>Mycobacterium</i> spp.
Alton et al. [68] (2015)	70.9	38.6	32.3	1.6	17.7	-	-	16.3	1.6 <sup>al</sup>	-
Ako et al. [28] (2014)	63.6	38.9	19.9	7.5	6.8	8.1	4.9	13.9	-	-
Avenali R [104] (2016)	69.6	34.8	30.4	4.3	-	13.0	-	8.7	-	-
Baker et al. [4] (1975)	53.8	-	-	-	7.6	12.8	10.3	12.8	2.6 <sup>b)</sup>	-
Connor et al. [16] (2013)	61.1	29.9	31.2	2.6	9.1	-	-	20.8	-	1.3
Grewal S [105] (2006)	74.8 <sup>d)</sup>	-	-	-	7	2.4	3.3	3.5	1.4 <sup>d)</sup>	1.1
Karikari et al. [42] (2009)	60.6	31.8	28.8	9.6	4.8	-	10.6	11.5	2.9 <sup>el</sup>	-
Kim et al. [72] (2014)	74.6	51.3	16.9	6.4	11.8	4.5	5.6	7.9	3.7	-
Ma et al. [48] (2012)	53.8	-	-	-	15.3	7.6	-	62.9 <sup>f)</sup>	-	-
Patel et al. [10] (2014)	70	40	30	4	6	3	2	10	5	-
Reihsaus et al. [3] (2000)	73.1	-	-	4.6	7.7	4.9	3.3	8.1	-	0.12
Sendi et al. [20] (2008)	60	-	-	4.5	14	16.5	-	-	-	<1
Shah et al. [44] (2018)	54	40	14	5.6	9.9	2.9	3.1	17	4.7 <sup>gl</sup>	1.3
Shweikeh et al. [47] (2017)	43.75	12.5	31.25	6.25	18.75	18.75	-	12.5	-	-
Spernovasilis et al. [71] (2017)	35	19	14.3	15	10	20	0	10	-	0
Suppiah et al. [66] (2016)	64.1	43.6	20.5	8.0	9.0	3.3	-	12.5	4.6 <sup>h)</sup>	-
Vakili et al. [8] (2017)	59.4	43.6	15.8	-	13.9 <sup>i)</sup>	4.9	3.0	16.8	2.0 <sup>l)</sup>	-
Zhu et al. [9] (2014)	40	23	-	-	6	11	5	10	-	-

Values are presented as %.

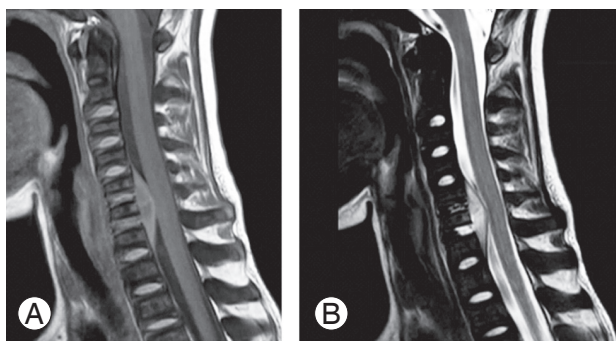
MSSA, methicillin-sensitive *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*.

Listing of specific entities as listed in the literature cited: <sup>a)</sup>*Clostridium glabrata*. <sup>b)</sup>*Diplococcus pneumoniae*. <sup>c)</sup>Includes *Staphylococcus aureus/epidermidis/mitis/sp.*, coagulase-negative staphylococci. <sup>d)</sup>*Neisseria*, *Acinetobacter*, *Brucella* sp., *Clostridium*, *Actinomyces*, *Propionibacterium*, *Nocardia*; parasites 0.36%. <sup>e)</sup>Fungi 13%. <sup>f)</sup>Fungal 1.7, parasites 0.15. <sup>g)</sup>*Anaerobe*, *Enterococcus*, and other organisms (*Candida* in 0.66% of cases). <sup>h)</sup>Includes *Anaerobe*, *Enterococcus* (4.6%), and other organisms (*Candida* in 3% of cases). <sup>i)</sup>Including mixture of *Streptococci*, *Enterococci*, and coagulase-negative *Staphylococcus*. <sup>j)</sup>Including *Brucella* and *Propionibacterium acnes*.

## Radiology

Advanced imaging is fundamental to the diagnosis of SEA. Several algorithms designed to improve the time to diagnosis in SEAs incorporate advanced imaging at the beginning of the decision tree [19]. An emergent magnetic resonance imaging (MRI) is mandatory in patients with severe back pain accompanied by new onset or progressive neurological deficit. Other indications for an emergent or urgent MRI include severe back pain in the setting of recent bacteremia or after procedures such as spinal injection, surgery, and catheterization. Furthermore, in patients with severe back pain and elevated levels of infectious markers (erythrocyte sedimentation rate [ESR]/C-reactive protein [CRP]/white blood cell [WBC]), or in patients with pertinent risk factors for SEA such as diabetes, immunodeficiency, and IVDU, the threshold to obtain urgent or emergent advanced imaging should be low [19]. Advanced imaging should also be considered in patients who present repeatedly to the emergency department with back pain. It cannot be overemphasized that the diagnosis of SEA is often delayed, and the prompt initiation of MRI may remediate this problem [22,58].

The ideal study to evaluate a patient with SEA is an MRI of the entire spine, with and without contrast. The characteristic findings of SEA on MRI include a high signal on T2-weighted imaging (T2WI) and a low signal on T1-weighted imaging (T1WI) [59] (Fig. 1). It is important to consider that epidural abscesses are not well appreciated on precontrast T2WI, as the abscess displays similar high-intensity signals as those of CSF. Precontrast T1WI is useful in detecting vertebral body and disc involvement. Postcontrast images are useful in defining the anatomical



**Fig. 1.** (A, B) Typical MRI demonstrating low signal intensity of an anterior cervical spinal epidural abscess on T1 weighted MRI and high signal intensity on T2 weighted imaging. MRI, magnetic resonance imaging.

location and the extent of an abscess, as well as the presence of spinal cord compression [59].

Broad differential diagnoses exist for SEAs, which include vertebral metastasis, epidural hematoma, disc disease (extruded or migrated discs), and vertebral osteomyelitis or osteodiscitis without SEA, among others. When the MRI, with and without intravenous contrast, is nondiagnostic, other imaging modalities may be considered.

Magnetic resonance myelography has been demonstrated to be highly sensitive in the diagnosis of SEAs [23,60]. CT myelography is less sensitive, although it may be the best imaging modality in cases where magnetic resonance modalities are contraindicated [20]. If possible, myelography should be avoided when there is a high index of suspicion for SEAs, due to the potential to spread the infection to the subarachnoid space [20]. In addition, CT myelography may demonstrate a myeloblock or thecal sac compression at the level of the pathology, but it may fail to demonstrate the cause of the compression, given the limitations of CT in soft tissue imaging. Nonetheless, this modality may be considered in patients with contraindications to MRI [61].

In the case that an initial imaging modality is nondiagnostic, and the index of suspicion for SEAs remains high, repeat imaging studies are mandatory. There is no consensus on the optimal timing or the modality of repeat imaging studies [20]. In cases where new-onset neurological deficits are encountered, or if a patient's symptoms do not improve after the initiation of empiric antibiotic therapy, an urgent repeat imaging should be performed. The authors of this paper recommend MRI, with and without intravenous contrast, of the entire spine as the first line of repeat imaging or CT, with and without intravenous contrast, in patients who cannot undergo MRI.

Nuclear imaging studies may also be considered in unique cases. Triple-phase bone scans with technetium-99m-labeled bisphosphonates have limited sensitivity and specificity for the diagnosis of vertebral osteomyelitis; however, this can be improved when combined with a gallium-67 scan [62]. Although not currently commercially available, indium-biotin scans may have a future role in the diagnosis of SEAs or vertebral osteomyelitis, as it appears this tracer is preferentially taken up by bacteria and does not accumulate in normal bone [63]. Finally, F-fluorodeoxyglucose-positron emission tomography may be the most useful among the nuclear imaging studies for the diagnosis of SEAs, as studies have demonstrated excellent



**Fig. 2.** Magnetic resonance imaging with contrast demonstrating a ring-enhancing lumbar spinal epidural abscess.

results in differentiating between infection and degenerative changes [64,65].

Finally, the enhancement pattern observed on MRI may help direct medical or surgical management of SEAs. Homogenous enhancement may correspond to an abscess with an inflammatory tissue in the absence of a purulent collection. Peripheral or ring enhancement may indicate the presence of purulent fluid or true abscess [59]. These imaging patterns may correlate with the responsiveness of an SEA to medical versus surgical management. In case of a true abscess, the necrotic center is relatively avascular and thus has less accumulation of the contrast material, resulting in the typical ring-enhancing pattern (Fig. 2). This pathophysiology also explains why ring-enhancing abscesses are less amenable to antibiotic therapy, as the center of the abscess does not receive adequate vascular supply to treat the infection with systemic antibiotics.

### Medical versus Surgical Management of Spinal Epidural Abscesses

There is a limitation of studies intended to guide the initial medical versus surgical management of SEAs, as the majority of them are small, retrospective reviews of a single institutional experience. SEA is a rare entity, and there are no studies with sufficient statistical power to detect significant differences in the outcomes of initial medical

versus surgical management. Currently available treatment guidelines for SEAs are supported by case series, cohort studies, and expert opinions ranging in level of evidence from II to VI. In addition, the reported conclusions are often driven by the patient population, the spinal level of the SEA, and the location of the SEA in relation to the spinal cord.

In a case series study of 104 patients at a single center performed over a decade earlier, Karikari et al. [42] stated “Our data do not support the hypothesis that patients treated without early surgery are more likely to have a poor outcome.” However, in that study, 25% of patients who were managed surgically improved, whereas only 11% of patients who were managed medically improved. Moreover, 65.4% of patients had ventral SEAs, which may be more amenable to medical management in general. Conversely, Suppiah et al. [66] performed a comprehensive review of the literature over a period of 25 years, including 1,843 patients, and identified the involvement of dorsal or circumferential SEAs in 49% of the patients. This research group favored early surgical intervention, citing it as the “optimal treatment” for patients with neurological deficits [66]. They also reported that SEAs are surgical emergencies that must be addressed immediately to avoid potential neurological damage caused by direct spinal cord compression, vascular compromise, or mechanical instability. Therefore, retrospective reviews may bias conclusions toward specific treatment modalities when the anatomical location and the orientation of the abscess vary in the reviewed population.

Concurrently, Wheeler et al. [67] performed a retrospective review of 37 SEA cases and concluded that “the current published literature does not support the widespread use of nonsurgical therapy for spinal epidural abscess.” More recently, Siddiq et al. [29] concluded that “Patients with spinal epidural abscess can be safely and effectively treated with conservative medical treatment without the need for surgery.” Their study may have a selection bias, as patients with more than two vertebral levels involved in the SEA were selectively treated surgically as were those with marked neurological abnormalities. Moreover, the only deaths reported in their study occurred in medically managed patients, and the authors conceded that emergency surgical decompression is the treatment of choice for patients with moderate to severe neurological symptoms at the time of presentation [29].

A retrospective study conducted by Patel et al. [10]

reviewed the outcomes of 128 patients with SEAs treated with initial medical or surgical management. Of 51 patients initially treated medically, 21 (41%) ultimately failed and required subsequent surgical intervention. Moreover, patients who were medically managed had higher average pretreatment motor scores; however, their return of motor function was significantly less than that in the surgically managed group [10]. The four parameters that correlated best with medical failure were (1) diabetes, (2) CRP level >115, (3) WBC counts >12.5 cells/mm<sup>3</sup>, and (4) positive blood cultures [10].

For patients with SEAs that are exclusively confined to the cervical region, Alton et al. [68] cautioned against the sole use of medical management, as they observed a 75% failure rate in their study cohort.

Recently, there has been a change in the initial approach to SEAs. In the 2 decades preceding 1997, 87.3% of patients with SEAs were managed surgically [28]. However, a large retrospective review of 1,095 patients with SEAs revealed that 40% of the patients were initially treated medically and 60% were initially treated surgically [28].

Caution must be applied in this approach, because medical management failed in 6%–49% of cases [28]. Although controversy exists regarding the best initial approach for medical versus surgical management, we have compiled a table of relevant factors affecting the success of surgical versus medical management in the setting of SEAs (Table 3). In addition to patient-specific risk factors and comorbidities, spinal cord anatomy and the location of an SEA may be vital to the success of medical or surgical management [69–71].

The majority of authors investigating SEAs view the pathology as a single infectious entity in the spine. However, one could argue that the spinal cord ends at the conus medullaris and the impact of an abscess below the cord is fundamentally different from that of an abscess above the level of the conus medullaris. One could further argue that an abscess in the lumbar spine is a fundamentally different disease process than an abscess in the cervical spine. Table 3 references the factors that may guide the initial treatment modality for patients with SEAs.

**Table 3.** Indication for initial medically versus surgical management in spinal epidural abscess

Variable	Surgical	Medical
Age	Greater than 65 years of age [66,72,106]; greater than 50 years of age [26]	
Co-morbidity	Diabetes mellitus [10,44,57,66,72,106]; active malignancy [44]	Non-diabetic
C-reactive protein greater than 115	Yes [10]	C-reactive protein less than 115
Leukocytosis greater than 12.5	Yes [10]	Leukocytosis less than 12
Microbiology	Methicillin-resistant <i>Staphylococcus aureus</i> [66,71,72,106]	-
Positive blood cultures	Yes [10]	No
Sepsis	Yes [66]	No [66]
Spinal level	Cervical [66,68,107] or cervicothoracic [66]; more than 5 level involvement [25]	Lumbar (below conus medullaris) [66]; abscess involvement is so extensive surgery is not feasible [26]
Anatomic location	Dorsal circumferential [42]	Ventral [42]; dorsal location [44] <sup>a)</sup>
Spinal instability	Instability [28,66] or pathologic or compression fracture at affected levels [44]	Stable [66]
Baseline neurologic status	Neurologically symptomatic [16,66] especially with neurologic deficit involving spinal cord [72] or motor weakness on presentation [44]; pelagic for <72 hr [42]; Sendi [20]; neurologically symptoms of less than 36-hour duration [20,30,106]; a relative risk factor, but probably less predictive is sensory deficit on presentation [44]	Neurologically intact [5,43]; pelagic for >72 hr [20,42,108]; complete spinal cord injury ≥36 hr [16] to ≥48 hr prior to presentation [1]
Decline in neurologic function	Yes [10]	No
Radiographic findings	Ring-like enhancement on magnetic resonance imaging [109] <sup>b)</sup>	-

<sup>a)</sup>Based on data of exclusively medically treated patients with low incidence of dorsal involvement. <sup>b)</sup>Enhancement of the disc, vertebral body, or para-/intraspinous soft tissues is seen in 94%–100% of patients with “spinal infection”, however, may not be evident in severely immunocompromised patients [110].



## Abscess Location as a Guide to Treatment Approach

The success of medical versus surgical treatment modalities is directly associated with the anatomical location, size, and the orientation of the abscess in relation to the spinal cord [42]. For instance, the management of cervical abscesses is not similar to that of lumbar abscesses and ventral abscesses, and it is also inherently different from that of dorsal and circumferential abscesses [42,72]. One could argue that abscesses below the spinal cord are a fundamentally different disease processes than those above the spinal cord. This is comparable to cervical disc herniation causing myelopathy (a condition that most of spine surgeons would indicate for surgical decompression) compared with lumbar disc herniation causing radiculopathy (a condition that evidence-based medicine suggests is initially managed with conservative measures). Although both these conditions are caused by disc herniations, the location of the pathology is important to the natural history of the disease and the successes of surgical versus conservative measures. Provided that the pathophysiology of neurological deficits in SEAs is believed to be largely due to compression, we postulate that the location of an abscess in the spine may dictate the success of medical versus surgical management. Table 4 outlines the anatomical distribution of SEAs reported in the literature.

Although the authors of this review ascribe to the theory that neurological deficits can largely be attributed to direct compression of the neuronal elements, other pathomechanisms for neuronal deficits have also been implicated. Local disruption of the microvasculature adjacent to an SEA secondary to venous stasis, thrombosis of spinal arteries, or local inflammatory changes may be responsible for some part of neurological deficits detected in SEAs [73-75]. This hypothesis may offer some clarification for why it is difficult to predict the timing of onset of neurological deficits in SEAs. This theory has not been collectively endorsed [1,20].

Dorsal abscesses are more likely to be associated with cord compression than ventral abscesses. In a cohort study of patients who improved well with medical management, 65.4% of the SEAs were exclusively ventral and 34.6% were exclusively dorsal [42]. In that cohort, although medical management was generally recommended, patients with dorsal orientation of SEAs were much more likely to present with paraplegia or quadriplegia. Patients with lumbar

involvement, who comprised the largest group in the study, did not improve with medical management [42].

Shah et al. [44] reviewed 367 patients who were initially managed medically and reported good outcomes. Their study group had significant selection bias, as the initial surgical management was an exclusion criterion. Only 8.3% of cases involved the cervical spine, and 71% of them were below the conus medullaris [44]. Regarding the orientation of the abscess, 83% of their study patients had a ventral component, with 66% being exclusively ventral and only 16% being located exclusively in the dorsal orientation. Their study demonstrated excellent results of nonoperative management of SEAs. Physicians must note the success achieved in the study of Shah et al. [44] in medically managing ventral SEAs and SEAs below the conus medullaris with medical interventions. As the spinal cord ends at the L1-2 level, there is more space and decreased risk of compression with space-occupying lesions in the lumbar spine. Above this level, the same is not true, and medical management of SEAs may not be as successful.

In contrast to the study of Shah et al. [44] where 66% of abscesses were exclusively ventral, Alton et al. [68] performed a study of cervical SEAs in which 55% of the patients had dorsal abscess components (33.9% dorsal and 21% circumferential). They concluded that early surgical intervention resulted in favorable outcomes compared with medical management. In addition, Patel et al. [10] advocated for initial surgical treatment of SEAs. In their study cohort, 65% of the patients had dorsal or circumferential involvement and 39.5% had a cervical SEA.

Dorsal SEAs are much more likely to present with neurological deficits than ventral SEAs [42]. This suggests that dorsal and ventral SEAs are two distinct entities and should be treated accordingly. Neural compression occurs early in the pathogenesis of dorsal SEAs, whereas ventral SEAs are more commonly associated with discitis or osteomyelitis and present with systemic symptoms (i.e., fevers) before neurological deficits [17,21,42].

Patients with a history of IVDU present a unique set of challenges. These patients have more cervical involvement, less posterior involvement (29% versus 66%), more circumferential abscesses (39% versus 27%), a higher rate of paralysis on presentation, a higher incidence of skip lesions (approximately 20%), and are more likely to be on antibiotics at presentation [31]. Furthermore, they have a higher rate of early hardware failure and postoperative neurological deterioration [31,76]. Still, this patient

**Table 4.** Abscess location

Study	Type of study	No. of patients	Cervical	Cervico-thoracic	Thoracic	Thoraco-lumbar	Lumbar	Lumbar-sacral	Sacral
Amadori et al. [11] (2017)	Single institutional retrospective review (>65 yr)	34	6		12		76	6	
Arko et al. [28] (2014)	PubMed review	646	24		30.8		48.1		
Artenstein et al. [7] (2016)	10-year, retrospective, tertiary-care, regional, academic medical center	162	25.9		34.0		56.2		29.0
	Single institutional retrospective review (<65 yr)	19	11		0		58		5
Comor et al. [16] (2013)	Single institutional retrospective review (11 yr)	77	23.4		50.6		26.0		
Karikari et al. [42] (2009)	Single institutional retrospective review (>10 yr)	104	17.0		31.8		51.1		
Lener et al. [26] (2018)	Review	24			31		48		
Patel et al. [10] (2014)	Single institutional retrospective review (6 yr)	128	35.9		39.1		54.7		23.4
Reihnsaus et al. [3] (2000)	PubMed review	725	19	7	35	7	18	12	0.4
Shah et al. [44] (2018)	Single institutional retrospective review (23 yr)	1,053	13	5.5	21	6.7	29	19	0.19
	Review (only medically treated)	8.5	3.3	19	6.8	37	22		0.5
Siddiq et al. [29] (2004)	Institutional retrospective	57	28		18		54		
	Literature review only Streptococcus pneumoniae	21	14.3	9.5	14.3		28.6	4.8	
Soehle et al. [21] (2002)	Single institutional retrospective review	25	32		20		48		
Suppiah et al. [66] (2016)	PubMed review (25 yr)	1,843 (based on 916 data points)	22.5		33.2		48.1		
Vakilii et al. [8] (2017)	Single institutional retrospective review (10 yr)	101	11.9		14.9		42.6		
Wang et al. [31] (2012)	Institutional prospective non-IVDA	44	18		47		34		
	Institutional prospective IVDA	44	78		9		13		
Wheeler et al. [67] (1992)	Case report	37	14-26		31-63		21-44		
Zimmerer et al. [41] (2011)	Single institutional prospective (4 yr)	36	9.6		17.3		53.4		9.6
Ziu et al. [9] (2014)	Single institutional retrospective review (IVDA)	34	8.8		23.5		57.8		

Values are presented as %, unless otherwise stated. Some cells are split to include specific population in cited study. IVDA, intravenous drug abuse.

population has a higher rate of motor score improvement with surgical decompression than the non-IVDU patient population (26 versus 9 points on the American Spinal Injury Association [ASIA] impairment scale and total motor score scale) [31].

### Treatment Algorithm and Isolation of Organisms

In the treatment of SEAs, it is important to recall the principles of source control and targeted antibiotic therapy. Fig. 3 depicts the authors' generalized algorithm describing our preferred approach to the diagnosis and treatment of SEAs while adhering to those principles. It is important to remember when considering this algorithm that the time to diagnosis or administer treatment and the surgeons' clinical experience weigh heavily on the optimal management of SEAs. This algorithm represents a framework for the diagnosis and management of SEAs and is not a rigid guideline.

Regardless of whether a patient will undergo interventional radiology drainage or open irrigation and debridement of an SEA, identifying the causative pathogen allows for targeted antibiotic/medical therapy. In general, culture swabs are discouraged as they often supply insufficient material for Gram staining and culture. In an ideal scenario, fluid/tissue samples should be sent for multiple aerobic, anaerobic, acid-fast bacteria, and fungal cultures. We advocate obtaining cultures in triplicate, when possible, to rule out contaminants. Although it is common practice is to grow fluid or tissue specimens on agar and broth media, recent evidence has demonstrated improved culture sensitivity when samples are grown in blood culture bottles [77]. Currently, microbiological culture remains the gold standard for identifying pathogens. However, newer techniques, including nucleic acid extraction with semi-automated sequencing, have shown promise as being more sensitive in the identification of pathogenic bacteria [78]. We recommend early multidisciplinary involvement of specialists in infectious diseases to recommend ideal techniques for the isolation of pathogens at one's specific institution.

Most of the published research recommends that antibiotics be withheld in stable patients until after biopsy is performed [79-81]. However, some literature reports no difference in culture sensitivity, even in patients who underwent biopsy at a median of 3 days after the initiation of

antibiotics [81].

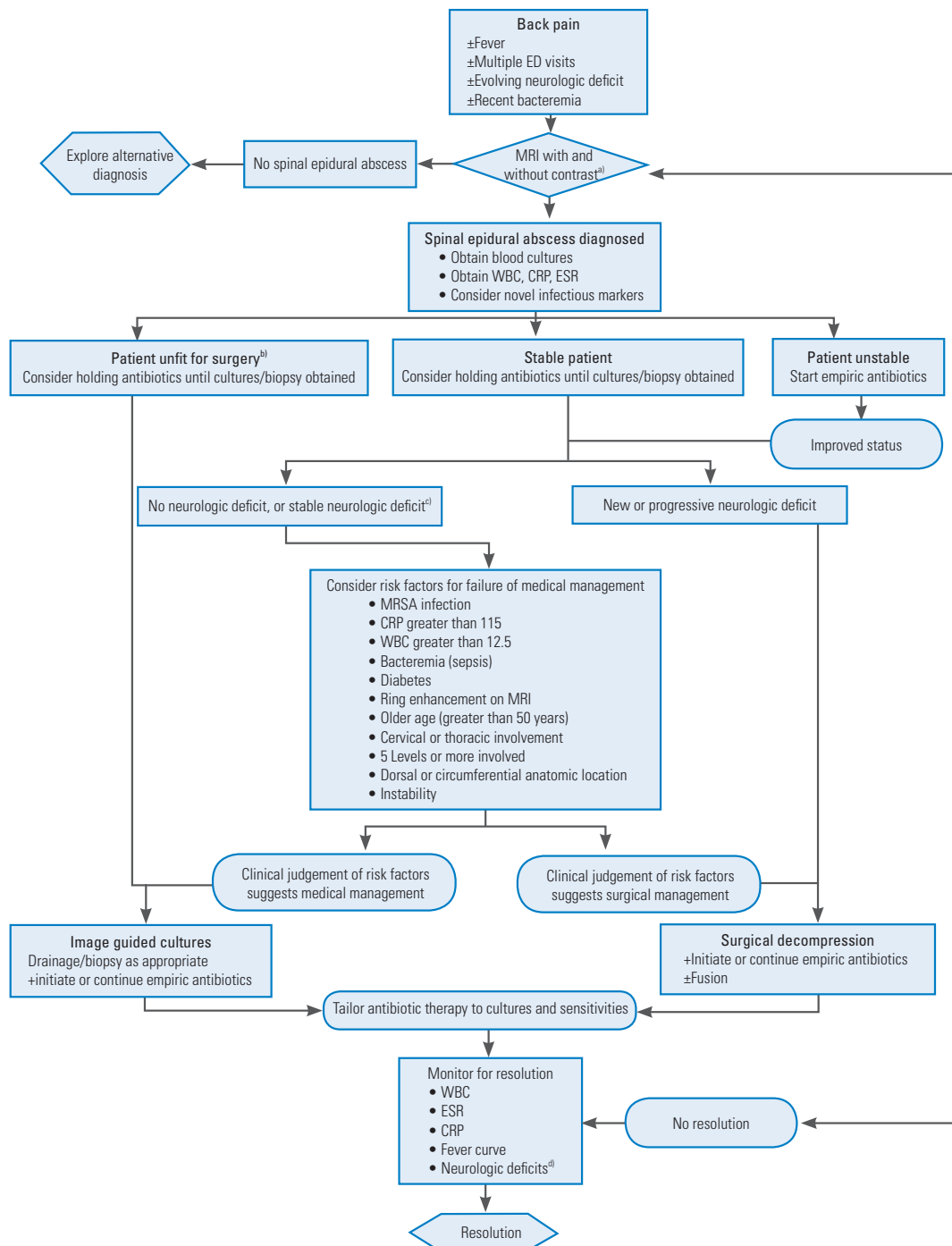
Guided aspiration, drainage, or biopsies may be indicated in multiple clinical situations. For instance, in frail patients who are medically unfit for surgical decompression, image-guided aspiration and decompression can provide adequate source control and accurate cultures. This minimally invasive procedure, in combination with antibiotic therapy, may be adequate to successfully treat a case of SEA. Other clinical situations where guided procedures may be appropriate include establishing a definitive diagnosis, treating a patient without neurological deficit, addressing small SEAs, and treating patients with isolated radiculopathy symptoms secondary to an SEA. Ultimately, multidisciplinary involvement, including a spinal surgeon and experts in interventional radiology, infectious diseases, and anesthesiology and the patient, will help guide the decision regarding medical versus surgical management. This topic is further explored in the section regarding medical versus surgical management of SEAs.

### Infectious Markers and Monitoring Outcomes

The role of inflammatory markers is of great importance to both diagnosis and monitoring of SEAs. The finding of an elevated WBC count in a routine laboratory testing can be indicative of an underlying inflammation or infection; however, it has limited sensitivity or specificity [82]. More sensitive markers such as serum ESR and serum CRP, have been routinely used to screen for and monitor inflammatory states. Various literature has demonstrated that a serum ESR level >30 mm/hr and a serum CRP level >10 mg/L achieved a sensitivity of >95% [83]. Both are useful markers for detecting an underlying infection, with CRP being more specific among the two. Recent research has also suggested that serum D-dimer may be even more sensitive than CRP in diagnosing infection, although less specific [84].

CRP may also be a useful marker for monitoring the resolution or nonresolution of infection after the initiation of treatment. With the presence of an inflammatory stimulus, the level of CRP is expected to double every 8 hours and peak at 36–50 hours. After the removal of that stimulus, the CRP level falls rapidly with a half-life of 19 hours [85]. We recommend monitoring the CRP level every 24–48 hours after the initiation of treatment, as values can be expected to decline rapidly after the initiation of appropriate treatment.

Procalcitonin has shown promise in distinguishing bac-



**Fig. 3.** Generalized algorithm describing our preferred approach to the diagnosis and treatment of spinal epidural abscess. It is important to remember when considering this algorithm that time to diagnosis/treatment and the surgeons clinical experience weigh heavily on the optimal management of spinal epidural abscess. This algorithm represents a framework for the diagnosis and management of spinal epidural abscess not a ridged guideline. ED, emergency department; MRI, magnetic resonance imaging; WBC, white blood cell; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate. <sup>a)</sup>MRI with and without intravenous contrast of the entire spine is the authors preferred imaging modality. If a patient cannot undergo this study, an alternative study should be chosen. <sup>b)</sup>A patient may be considered unfit for surgery if he/she (1) refuses any operative intervention, (2) has considerable medical risk factors, which are determined with input from the anesthesiologists that the risks of surgical intervention outweigh the potential benefits, and (3) has a concurrent medical condition which requires urgent intervention that surpasses the spinal epidural abscess. <sup>c)</sup>Stable neurologic deficit may be any neurologic deficits that existed prior to the onset of the current disease process. Additionally, any new deficit which is stable may not necessitate operative intervention. Some surgeons may choose to treat neurologic deficits consistent with radiculopathy with initial medical management. Again, considerations of the timing of presentation, and the severity of disease are not covered in this algorithm and weigh heavily on the decision to proceed. Finally, there is no substitute for a surgeon's clinical experience in the management of spinal epidural abscess. <sup>d)</sup>New onset neurologic deficits after management is initiated or the worsening of deficits are important clinical signs that should be investigated thoroughly possibly with repeat imaging. If neurologic deficits do not resolve after treatment that is not necessarily a sign of failed management.

terial and nonbacterial infections; however, it has lower sensitivity than CRP in diagnosing SEAs [86]. Other novel markers such as high-sensitivity-CRP, presepsin, and alpha-defensin have not been thoroughly investigated at this point, and specific diagnostic criteria cannot be recommended. Nevertheless, these markers may be of use in diagnosing or monitoring SEAs.

When possible, antibiotic therapy should be tailored to the offending pathogen and delivered via the route of highest penetrance, which is most often intravenous. There is some evidence indicating that oral antibiotics are as effective as intravenous antibiotics in the management of infection; however, the use of oral antibiotics in the initial or empiric treatment of SEAs is not common [87]. When no pathogen is identified, empiric antibiotics, including vancomycin plus ceftriaxone or Zosyn, are often the first line of empiric antibiotic treatment. When there is no response to these medications, the empiric treatment should be altered with co-management by specialists in infectious diseases.

Although the duration of treatment is variable, it should typically not be shorter than 6 weeks. Treatment duration can vary significantly between 6 weeks and multiple months depending on the type of infection. Moreover, in some cases, indefinite suppressive antibiotic therapy may be necessary. However, most often, CRP levels can be trended throughout the medical treatment. As CRP levels normalize, any underlying osteomyelitis or discitis is typically treated with a prolonged course of antibiotics. When an appropriate decrease in CRP levels is not observed, and the patient has new clinical signs or symptoms of disease progression or other infectious markers become elevated, further workup and management may be necessary. Fig. 3 outlines the typical treatment algorithm for patients with SEAs, including monitoring for the resolution of disease.

### Instrumentation during Infection

An isolated SEA is not generally associated with deformity or instability. However, when instrumented decompression is indicated, infection should not prohibit hardware placement. Decompression, with or without instrumentation, has been reported to have equivalent rates of reoperation and resolution of the infection [49,88,89], even at long-term follow-up [90,91].

In the setting of osteomyelitis, Chen et al. [92] have stratified the need for instrumentation to include (1) insta-

bility, (2) significant destruction of endplates, (3) abscess formation, (4) new neurological deficit, (5) local kyphosis, (6) septic pseudoarthrosis, and (7) refractory pain or infection. The literature strongly supports the paradigm that if neurological instability exists, decompression and instrumented spinal stabilization may be performed in a single stage, even in the presence of active infection [89-91,93-95]. If instrumentation is used, long-term clearance of infection may be more likely with titanium or titanium alloy implants than with stainless steel implants [93]. It appears that instrumentation of the infected spine may be a safe practice and should be considered when the spinal stability is compromised, even in cases of resistant organisms such as MRSA [49]. Immunosuppressed patients with vertebral osteomyelitis have a low risk of 3.13% (1/32) of developing recurrence after decompression and instrumentation [96]. Reoperation rates are similar between the decompression alone (19.44%) and instrumented decompression (17.1%) groups in the setting of spinal infection [49]. Other authors have reported that in the setting of SEAs, instrumented decompression not only has equivalent success rates as those of uninstrumented decompression, but it also may be associated with decreased mortality [94].

### Neurological Outcomes

Even when SEAs are well managed, neurological outcomes can be poor. In general, an early operative intervention is recommended, as delays in surgical intervention are associated with increased morbidity and mortality [30]. In a retrospective review of operative versus nonoperative management of SEAs, Connor et al. [16] demonstrated that approximately 80% of patients (79.2%) had improvements in neurological deficits following decompression. The authors also demonstrated that advanced patient age and more severe preoperative deficits correlated with poor neurological outcomes. Their study is only one example of the numerous studies conducted by authors who advocate for early surgical intervention to improve neurological and survival outcomes [16,68,97,98]. Perhaps most notably, Patel et al. [10] demonstrated that early surgery improved the neurological outcomes compared with surgical management delayed by a trial of medical management. In addition, more than 41% of patients in that cohort ultimately failed medical management and required surgical decompression. The patient group that ultimately failed medical management had net deterioration in their ASIA

motor score of 14.86 points compared to that in the other groups who demonstrated improvements [10]. In addition to the potentially devastating neurological outcomes associated with SEAs, there is potential for structural spinal sequelae, complications associated with the dissemination of infectious materials, such as endocarditis, or even death. The reported mortality rates associated with SEAs range from 3% to 25% [99].

### Medicolegal Cost

Throughout this article, we have emphasized the importance of early diagnosis and treatment of SEAs before the onset of permanent neurological damage. In addition to the immeasurable cost of human suffering associated with the sequelae of delayed treatment in SEAs, there is a substantial medicolegal exposure [100].

It has been observed that 61% of law suits pertaining to SEAs are settled outside of court or end with a ruling that favors the plaintiff [100]. The mean cost of a ruling in favor of a plaintiff is US \$5,277,468±US \$6,348,462, and settlements average at US \$1,914,265±US \$1,313,322 [100]. Plaintiffs who suffer a significant neurological morbidity are more likely to be awarded substantial settlements averaging US \$4,699,772±US \$5,369,684 [100]. Delayed time to imaging (33.75 versus 4 days), expert consultation (32.7 versus 2.8 days), and surgical intervention (33.5 versus 18.9 days) are the key factors associated with medical liability [101]. Specifically, delayed diagnosis, delayed treatment [102], and paralysis are independent risk factors for legal decisions in favor of the plaintiff [100]. Plaintiff verdicts were more common in patients who sustained significant neurological deficits secondary to their disease, and these plaintiffs were also awarded larger rulings [102].

When reviewing medicolegal liability, it is important to understand the factors that correlate with “failure to recover.” In the treatment of SEAs, “failure to recover” is affected by age (the single most important predictive factor), paralysis, renal failure, and a patient’s insurance status [15]. Medicare and underinsured patients fare far worse than those with private insurance [15]. Faber et al. [13] classified patients with SEAs into early surgery, delayed surgery, and medical management treatment groups. Patients who received early surgical interventions within 48 hours of admission were more likely to be privately insured [13]. This type of selection bias, either conscious or unconscious, has an enormous impact on patient morbidity and

mortality and adds to a significant medicolegal exposure for physicians.

### Conclusions

Early diagnosis and emergent management are vital in the successful treatment of SEAs. Educating physicians and instituting policies and practices to obtain urgent advanced imaging in patients with back pain or new-onset neurological symptoms or in patients who return to the emergency department for continued back pain, even without neurological symptoms, are vital to the early diagnosis of SEAs. Once diagnosed, assessing an abscess’ characteristics and classifying it based on its location, size, appearance on imaging, aberrant laboratory values, the patient’s comorbidity profile, and the association with neurological symptoms may determine whether an SEA is amenable to initial medical or surgical management. Early subspecialist involvement, including consultations in infectious disease, orthopedic or neurosurgery, and rehabilitation medicine, is vital. Continued research and high-quality studies would further illuminate the optimal management of SEAs.

### Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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