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Comparison of operative and nonoperative management of spinal epidural abscess: a retrospective review of clinical and laboratory predictors of neurological outcome

Clinical article

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Object. Spinal epidural abscess (SEA), once considered a rare occurrence, has showed a rapid increase in incidence over the past 20–30 years. Recent reports have advocated for conservative, nonoperative management of this devastating disorder with appropriate risk stratification. Crucial to a successful management strategy are decisive diagnosis, prompt intervention, and consistent follow-up care. The authors present a review of their institutional experience with operative and nonoperative management of SEA to assess morbidity and mortality and the accuracy of microbiological diagnosis.

Methods. A retrospective analysis of patient charts, microbiology reports, operative records, and radiology reports was performed on all cases involving patients admitted with the diagnosis of SEA between July 1998 and May 2009.

Results. Seventy-seven cases were reviewed (median patient age 51.4 years, range 17–78 years). Axial pain was the most common presenting symptom (67.5% of cases). Presenting signs included focal weakness (55.8%), radiculopathy (28.6%), and myelopathy (5.2%). Abscesses were localized to the lumbar, thoracic, and cervical spine, respectively, in 39 (50.6%), 20 (26.0%), and 18 (23.4%) of the patients. Peripheral blood cultures were negative in 32 (45.1%) of 71 patients. Surgical site or interventional biopsy cultures were diagnostic in 52 cases (78.8%), with concordant blood culture results in 36 (60.0%). Methicillin-resistant *Staphylococcus aureus* (MRSA) was the most frequent isolate in 24 cases (31.2%). The mean time from admission to surgery was 5.5 days (range 0–42 days; within 72 hours in 66.7% of cases). Outcome data were available in 72 cases. At discharge, patient condition had improved or resolved in 57 cases (79.2%), improved minimally in 6 (8.3%), and showed no improvement or worsening in 9 (12.5%). Patient age and premorbid weakness were the only factors found to be significantly associated with outcome ($p = 0.04$ and 0.012, respectively).

Conclusions. These results strongly support immediate surgical decompression combined with appropriately tailored antibiotic therapy for the treatment of symptomatic SEA presenting with focal neurological deficit. The nonsuperiority discovered in other patient subsets may be due to allocation biases between surgically treated and nonsurgically treated cohorts. The present data demonstrate the accuracy of peripheral blood culture for the prediction of causative organisms and confirm patient age as a predictor of outcomes.
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Key Words • **spinal epidural abscess** • **surgical decompression** • **central nervous system infection**

From its initial postmortem diagnosis in 1769 by Giovanni Battista Morgagni, spinal epidural abscess (SEA) was considered an almost universally fatal diagnosis.[15,16,20,25] The advent of decompressive laminectomy, as well the introduction of early antibiotic agents in the late 1930s, led to contemporary survival rates as high as 74%.[9,20] By the mid-1970s, accepted mortality rates had fallen to about 18%. At this time, SEA accounted for 0.2–1.2 cases per 10,000 hospital admissions.[4] This number has steadily increased over the succeeding decades, with current estimates of incidence at more than 2 cases per 10,000 admissions,[3,5,12,17,19,21] while mortality is relatively stable at 5%.[5] Many have attributed this near doubling to a combination of influences, including the widespread increase in intravenous drug abuse, an ever-aging population, and the increased prevalence of spinal implants and chronic vascular access.[5,17,19,21]

With steady improvement in mortality rates, many would expect a concomitant decrease in morbidity; however, continued reports quote significant morbidity in the range of 33%–47%.[3,11,20,21] The leading factor contributing

Abbreviations used in this paper: MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-sensitive *S. aureus*; SEA = spinal epidural abscess.

This article contains some figures that are displayed in color online but in black-and-white in the print edition.

to these poor outcomes is delay in—or missed—initial diagnosis, reported to occur in 11%–75% of cases.[5,7] The condition is often misdiagnosed in patients presenting with mild symptoms, especially those lacking any immediate neurological deficit, such as urinary tract infection, pneumonia, or degenerative spine issues, and patients may be treated with oral or parenteral antibiotics as a result of the misdiagnosis.

Medical therapy is often based upon broad-spectrum coverage initially, with antibiotic choice and duration tailored to the results of blood and/or tissue cultures. In 60% of patients with SEA, bacteremia will be detected on peripheral culture; however, especially in those patients beginning therapy prior to sampling, these results can often be negative or inconclusive.[3–6,12] Nonconcordance of culture results obtained from peripheral blood and operative or interventional biopsy samples raises significant questions as to the diagnostic accuracy of either modality.

The gold standard treatment, well supported by multiple published reports, consists of prompt surgical drainage in combination with systemic antibiotic therapy.[3–6,12,17,19,21] Final outcomes have been strongly and significantly correlated to both duration of the deficit and severity immediately prior to decompression.[4–6,11,12,27] Despite the overwhelming reproducibility of these findings, 4%–22% of patients continue to suffer irreversible paralysis.[4–6] Some authors have proposed that with earlier diagnosis due to improved imaging modalities, the results of nonoperative management may be similar to the results demonstrated with operative decompression.[1–3,7,14,22–24] However, neurological deterioration has been consistently demonstrated in a substantial number of patients even while receiving appropriate antibiotic agents.[3,4,6,12,26]

We endeavored to examine the cumulative experience regarding operative and nonoperative management of SEA at our institution. Of particular interest in our review were the predictive factors for improved outcome, as well as the accuracy of peripheral blood and tissue cultures in directing the care of these critically ill patients.

Methods

Prior to the collection of data, our protocol was reviewed and approved by the Institutional Review Board for the Protection of Human Research Subjects at the Louisiana State University Health Sciences Center–Shreveport.

Following approval, a hospital record search was conducted for all patients admitted or discharged with the diagnosis of intraspinal abscess under ICD-9-CM Diagnosis Code 324.1. A retrospective analysis of patient charts, microbiology reports, operative records, and radiology reports was performed for all cases involving patients admitted from July 1998 to May 2009.

Patient characteristics collected and recorded included age, sex, race, results of blood and/or tissue cultures, surgical treatment, date of admission, time to surgery, neurological condition at admission and discharge, discharge disposition, and imaging characteristics as documented by 1 of 2 board-certified neuroradiologists. Outcome was categorized for statistical analysis into 5 categories: death, worsened or no improvement, minimal improvement, improved, or resolved.

Patients were excluded from the study if they were less than 18 years of age, if they had concurrent intracranial pathology, or if requisite data could not be obtained for diagnosis of SEA.

Selection criteria for operative versus nonoperative management are determined on a case-by-case basis by the attending neurosurgeon. Generally speaking, it is standard practice within the department to regard all cases involving patients presenting with acute loss of motor strength or bowel and/or bladder control as surgical emergencies with consideration for operative decompression. Symptoms occurring within the previous 72 hours have historically been considered acutely presenting. Because our institution is a tertiary referral center, patients harboring SEA often arrive on transfer from outside facilities with varying lengths of stay and documentation of neurological status. In these instances, all attempts are made to confirm status via patient interview and/or medical record search. If those attempts are unsuccessful, any neurological change is considered of acute nature beginning from the time of arrival and is treated accordingly.

Statistical Analysis

Univariate analysis was performed utilizing the chi-square or Fisher exact test to compare individual variables to outcome and establish statistical significance (Table 1). Categorical factors (outcome, abscess location, causative organism) were similarly compared among operative and nonoperative cases (Table 2).

The Wilcoxon rank-sum or 2-sample t-test was used to determine significance among numeric factors (age, length of abscess, superior and inferior levels) associated with outcome among the surgery and nonsurgery groups.

Results for causative organism were divided into 4 groups for analysis, including negative, MRSA, MSSA, and other (this last for all organisms occurring less frequently). Among patients with both blood and tissue culture results, the χ statistic was used to test for agreement on determining the causative organism. If the results of one test were negative and those of another were positive, the result for the positive test was considered the causative organism.

Results

Seventy-seven cases were reviewed, involving 48 male and 29 female patients with a median age of 51.4 years (range 17–78 years). Fifty-seven patients were treated surgically and 20 were treated nonsurgically. Demographic and summary statistics with p values for associations with outcome are shown in Table 1. The mean craniocaudal length of SEA was 1.8 vertebral levels (range 1–5 levels), with a median of 1 vertebral level. Patients with more cranially localized SEA showed a trend toward worse outcomes when compared with those with a more caudal location; however, the difference failed to reach statistical significance. Increasing length of SEA similarly showed no statistical prediction for worse outcome at discharge. Patient age and preoperative weakness were the only factors found to be significantly associated with outcome. The patients whose condition had improved or who had resolution of SEA at discharge were younger (median 51.1 years, mean 49.6 ± 12.6 years, range 17.4–78.1 years) than those who did not

TABLE 1: Summary statistics on demographic variables and outcome*

Characteristic or Outcome Variable	Value (%)	p Value
male	48 (62.3)	0.06
African-American	27 (55.1)	0.73
causative organism by either tissue or BC		0.18
none (negative)	16 (20.8)	
MRSA	24 (31.2)	
MSSA	23 (29.9)	
other	14 (18.2)	
causative organism by tissue		0.25
none (negative)	14 (21.2)	
MRSA	21 (31.8)	
MSSA	20 (30.3)	
other	11 (16.7)	
causative organism by BC		0.21
none (negative)	32 (45.1)	
MRSA	18 (25.4)	
MSSA	14 (19.7)	
other	7 (9.9)	
agreement btwn tissue & BC	36 (60.0)	>0.99
anatomical location of abscess		0.10
cervical	18 (23.4)	
thoracic	39 (50.6)	
lumbar	20 (26.0)	
surgical intervention	57 (74.0)	0.71
laminectomy	47 (82.5)	
w/ discectomy	5 (8.8)	
w/ fixation	1 (1.8)	
anterolateral approach	8 (14.0)	
discectomy/fusion	2 (3.5)	
corpectomy	6 (10.5)	
washout	2 (3.5)	
outcome		
died, worsened, or no improvement	9 (12.5)	
minimal improvement	6 (8.3)	
improved	45 (62.5)	
resolved	12 (16.7)	
age (yrs)		0.04
mean	50.8 ± 12.3	
median	51.4	
range	17.4–78.0	
length of abscess (no. of vertebral levels)		0.12
mean	1.8 ± 1.0	
median	1.0	
range	1–5	
superior vertebral level†		0.06
mean	15.3 ± 7.8	
median	18.0	
range	1–24	
inferior vertebral level†		0.12
mean	17.1 ± 7.5	
median	20.0	
range	4–25	
no. of days to surgery from admission (for operative patients)		0.12
mean	5.5 ± 8.8	
median	2.0	
range	0–42	

* Outcome data were not available in 5 cases; thus analysis for outcome is based on 72 cases. Abbreviation: BC = blood culture.

† For the purpose of calculating abscess length, the vertebral levels were numbered consecutively starting with C1 (1 refers to C-1, 2 refers to C-2, etc.).

show improvement (median 57.0 years, mean 57.0 ± 9.6 years, range 41.2–76.4 years; p = 0.04) (Fig. 1).

Axial pain was the most common presenting symptom (reported in 67.5% of cases). Presenting signs included focal weakness (in 55.8% of cases overall), radiculopathy (in 29.9%), and myelopathy (in 5.2%). Focal weakness was noted in 64.9% of patients in the operative cohort versus 30.0% among the nonoperative cohort (p = 0.009). The incidences of axial pain, radiculopathy, and myelopathy, respectively, were 65.0%, 35.0%, and 0% among the nonoperative cohort and 68.4%, 28.1%, and 7.0% among the operative cohort. Data regarding neurological outcome upon discharge were unavailable in 5 (6.5%) of the 77 cases; thus the outcome analysis was based on 72 cases. The patients' condition was improved or resolved in 57 (79.2%) of 72 cases, with minimal improvement in 6

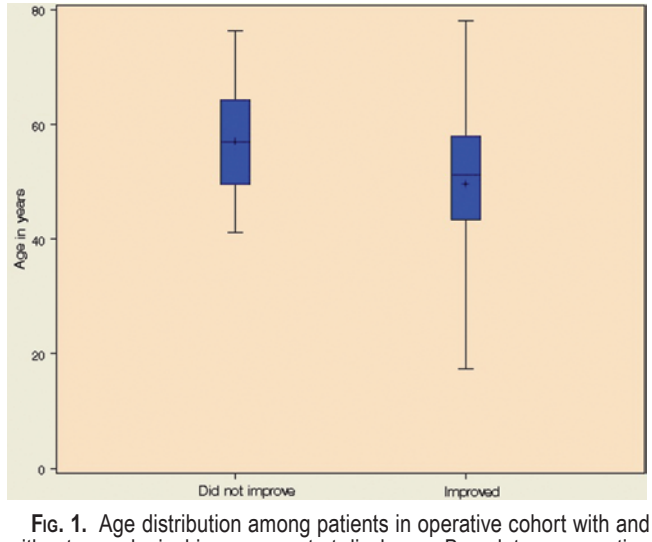

Fig. 1. Age distribution among patients in operative cohort with and without neurological improvement at discharge. Box plots representing median age bounded by the first and third quartiles in operative cases, comparing the age of patients who demonstrated neurological improvement at discharge with those showing no improvement.

TABLE 2: Comparisons between operative and nonoperative cases*

Factor	Operative (n = 57)	Nonoperative (n = 20)	p Value
presenting sign			
axial pain	39 (68.4)	13 (65.0)	0.787
radiculopathy	16 (28.1)	7 (35.0)	0.580
myelopathy	4 (7.0)	0 (0.0)	0.568
focal weakness	37 (64.9)	6 (30.0)	0.009†
comorbidities‡			
hypertension	24 (42.1)	10 (50.0)	0.606
previous focus of infection	22 (38.6)	2 (15.0)	0.059
endocarditis	7 (12.3)	1 (5.0)	0.672
spider bite	4 (7.0)		0.568
diabetes	15 (26.3)	5 (25.0)	>0.99
drug abuse	11 (19.3)	2 (10.0)	0.495
renal disease	9 (15.8)	4 (20.0)	0.732
dialysis	7 (12.3)	3 (15.0)	0.714
hepatitis C	6 (10.5)	1 (5.0)	0.669
congestive heart failure	4 (7.0)	2 (10.0)	0.647
cirrhosis	3 (5.3)		0.564
rheumatoid arthritis	3 (5.3)		0.564
COPD	2 (3.5)	1 (5.0)	>0.99
HIV infection	1 (1.8)	2 (10.0)	0.164
alcohol abuse	1 (1.8)	3 (15.0)	0.052
causative organism (swab or BC)			0.010
negative (n = 16)	8 (14.0)	8 (40.0)	
MRSA (n = 24)	21 (36.8)	3 (15.0)	
MSSA (n = 23)	20 (35.1)	3 (15.0)	
other (n = 14)	8 (14.0)	6 (30.0)	
anatomical location of abscess			0.360
cervical (n = 18)	15 (26.3)	3 (15.0)	
thoracic (n = 20)	16 (28.1)	4 (20.0)	
lumbar (n = 39)	26 (45.6)	13 (65.0)	
outcome			>0.999
significant improvement (n = 57)	43 (78.2)	14 (82.4)	
no improvement, worsening, or death (n = 15)	12 (21.8)	3 (17.6)	
data not available (n = 5)	2	3	
age in yrs			0.330
mean	51.6 ± 11.5	48.5 ± 14.2	
median	52.0	51.2	
range	19.0–78.0	17.4–76.4	
length of abscess (no. of vertebral levels)			0.480
mean	1.8 ± 1.1,	1.9 ± 1.0	
median	1.0	2.0	
range	1–5	1–4	
superior vertebral level			0.330
mean	14.6 ± 7.9	17.0 ± 7.1	
median	15.0	20.5	
range	1–4	1–24	
inferior vertebral level			0.320
mean	16.5 ± 7.6	18.9 ± 7.1	

(continued)

TABLE 2: Comparisons between operative and nonoperative cases* *(continued)*

Factor	Operative (n = 57)	Nonoperative (n = 20)	p Value
inferior vertebral level *(continued)*			0.320
median	16.0	22.5	
range	4–25	4–25	

* Values in parentheses are percentages. Abbreviation: COPD = chronic obstructive pulmonary disease.
† Statistically significant ($p < 0.01$).
‡ Other reported comorbidities included coronary artery disease in 2 patients and acute lymphoblastic leukemia, lymphoma, Crohn disease, nasopharyngeal carcinoma, syphilis, obesity, and pancreatitis in 1 patient each.

(8.3%), and no improvement or worsening condition seen in 9 (12.5%). In the operative cohort, patients presenting with weakness were significantly more likely to have an improved or resolved outcome than to have no improvement (24 [64.9%] of 37 vs 13 [35.1%] of 37, $p = 0.012$; Table 3). There was no statistically significant association between weakness at presentation and improved outcome in the nonoperative cohort, however ($p = 0.193$).

Postoperative complications occurred in 22 (38.6%) of 57 patients. The most commonly reported morbidities included wound infections in 4 (7.0%) patients and deep vein thrombosis, kyphotic angulation requiring fixation, and respiratory failure in 3 patients (5.3%) each (Table 4). The most common complication experienced among medically treated patients was fungemia, occurring in 10%. The occurrence of respiratory failure, deep vein thrombosis, and myocardial infarction was compared between the operative and nonoperative cohorts, and no significant trend could be identified. One patient in the nonoperative cohort died while hospitalized (overall in-hospital mortality rate 1.3%).

All surgically treated patients underwent decompression of the affected vertebral segments. In the majority of cases (82.5%), this was achieved via a posterior laminectomy alone. In 5 cases (8.8%), posterior decompression was augmented by discectomy, and in 1 case (1.8%) by posterolateral pedicle screw fixation. The anterior or anterolateral approach was used in 8 cases (14.0%), with 2 patients undergoing discectomy and fusion and 6 (10.5) undergoing corpectomy and fusion. Treatment was augmented with pedicle screw fixation in 1 case (Table 1). Postoperatively, all patients received intravenous antibiotic therapy tailored to the specific organism identified via operative or blood culture. The infectious disease service was consulted for determination of optimal length of treatment; patients were treated with antibiotics for a mean and median of 6 weeks postoperatively (range 2–24 weeks).

The mean time to surgery was 5.5 days (range 0–42 days), with 66.7% of the patients (38 of 57 patients) undergoing surgery within the first 72 hours. Of these patients, 65.8% presented with axial pain, 28.9% with symptoms of radiculopathy, 5.3% with evidence of myelopathy, and 68.4% with focal weakness of upper and/or lower extremities. In the operative cohort, data regarding outcome at discharge were available for 55 of 57 cases. For the 43 patients whose condition was improved or resolved at discharge, the mean time to surgery was 6.3 ± 9.6 days (median 2 days), whereas the 12 patients showing no improvement underwent surgery at an average of 3.2 ± 5.1 days (median 1 day) after admission ($p = 0.12$). Twenty-six (72.2%) of 36 patients who underwent decompression within the first 72 hours showed improvement or had their symptoms resolved at discharge. Patients having surgery later than 72 hours postadmission showed improvement or had their symptoms resolved at discharge in 89.5% of cases (17 of 19). Patients in this group presented with symptoms of axial pain in 73.7% of cases, radiculopathy in 26.3%, evidence of myelopathy in 10.5%, and focal

TABLE 3: Comparison of outcomes and presentation among patients in operative cohort*

Variable	Improved or Resolved	No Improvement	p Value
no. of patients	43	12	
time to surgery (days)	6.3 ± 9.6	3.2 ± 5.1	0.120
mean			
<72 hrs (n = 36)	26 (72.2)	10 (27.8)	0.183
>72 hrs (n = 19)	17 (89.5)	2 (10.5)	
preop signs			
axial pain (n = 39)	32 (82.0)	7 (17.9)	0.107
radiculopathy (n = 16)	13 (81.2)	3 (18.7)	0.735
myelopathy (n = 4)	4 (100)	0	0.563
focal weakness (n = 37)	24 (64.9)	13 (35.1)	0.012†

* Outcome data were available for 55 patients in the operative cohort. Values represent numbers of patients (%) unless otherwise indicated.
† Statistically significant ($p < 0.05$).

TABLE 4: Postoperative morbidity in 57 cases

Morbidity	No. of Cases (%)
wound infection	4 (7.0)
deep	2 (3.5)
superficial	2 (3.5)
deep vein thrombosis	3 (5.3)
kyphotic angulation	3 (5.3)
respiratory failure	3 (5.3)
ileus	2 (3.5)
pneumatosis coli	1 (1.8)
pulmonary embolism	2 (3.5)
myocardial infarction	1 (1.8)
pneumothorax	1 (1.8)
splenic laceration	1 (1.8)
hardware failure	1 (1.8)

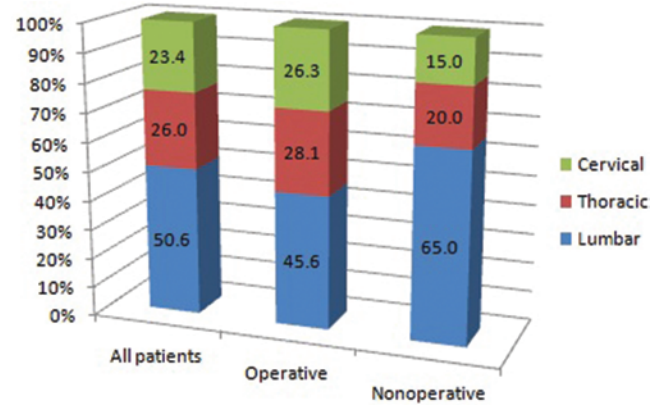

Fig. 2. Anatomical distribution of SEA at the lumbar, thoracic, and cervical levels. Bar graph representing the distribution of cases by abscess location among operative and nonoperative cases. No significant difference could be identified between operative and nonoperative cases.

weakness in 57.9%. Comparison of presenting symptoms and number of spinal levels affected among operative subsets failed to demonstrate statistically significant differences (Table 5). Subsequent analysis showed no significant effect association between outcome and time to surgery (p = 0.18) (Table 3).

Abscesses were localized to the lumbar spine in 39 patients (50.6%) and to the thoracic and cervical regions in 20 patients (26.0%) and 18 patients (23.4%), respectively. In the operative cohort, the proportions of patients with abscesses located in the lumbar, thoracic, and cervical spine were 45.6%, 28.1%, and 26.3%, respectively. In the nonoperative cohort, the corresponding percentages were 65%, 20%, and 15% (Fig. 2). The SEA distribution in these locations did not differ significantly between the 2 cohorts (p = 0.36). The mean value of abscess length in terms of number of vertebral levels was 1.8. Two patients (2.6%) had previously undergone spine surgery with instrumentation placement.

The results of blood cultures were negative in 32 (45.1%) of the 71 patients for whom blood cultures were obtained. Twenty-seven (38.0%) of 71 patients with blood culture results had a documented dose of intravenous antibiotics before the blood sample was obtained, with the elapsed time ranging from 1 day to 3 months. Timing of antibiotic therapy was found to have no effect on likelihood of negative blood culture results (p = 0.630). Blood cultures were not performed in 6 patients (10.5%) of the patients in the operative cohort (Table 6). Surgical site or interventional biopsy cultures were diagnostic in 52 (78.8%) of 66 cases, with concordant blood culture results in 36 (69.2%) of these 52 cases. Twenty-eight (42.4%) of these 66 patients received their first dose of intravenous antibiotics prior to the initiation of the surgical procedure (range 1 day–3 months). Timing of antibiotic dosage was found to have a statistically significant effect on the likelihood of negative intraprocedure culture results (p = 0.001). Methicillin-resistant *Staphylococcus aureus* was the most frequently identified organism in the entire cohort (n = 77) isolate, being identified in 24 cases (31.2%). "Other" causative organisms included MSSA in 23 (29.9%); *Staphylococcus epidermidis*, *Streptococcus bovis*, *Streptococcus pneumoniae*, *Enterococcus faecalis* in 2 (2.6%) cases each; and *Candida albicans*, *Orchobactrum anthropi*, *Streptococcus oralis*, *Mycobacterium tuberculosis*, and *Prevotella intermedia* in 1 (1.3%) case each. Methicillin-resistant *S. aureus* (36.8%) or MSSA (35.1%) was isolated significantly more frequently in operative patients than in nonoperative

TABLE 5: Comparisons between operative patients undergoing intervention within 72 hours of and more than 72 hours after admission*

Factor	<72 Hrs (n = 38)	>72 Hrs (n = 19)	p Value
presenting sign			
axial pain	25	14	0.555
radiculopathy	11	5	>0.99
myelopathy	2	2	0.594
weakness	26	11	0.558
length of abscess (in vertebral levels)			
mean	1.95 ± 1.1	1.53 ± 0.9	0.173
median	2	1	
range	1–5	1–4	

* Values represent numbers of patients unless otherwise indicated.

TABLE 6: Effect of timing of intravenous antibiotic treatment on results of intraoperative or blood cultures*

Timing & Effect of IV Antibiotics	No. of Cases (%)	p Value
preoperative	28 (42.4)	<0.01
negative BC	12 (42.9)	
positive BC	16 (57.1)	
pre-BC	27 (38.5)	0.63
negative BC	13 (48.1)	
positive BC	14 (51.9)	

* IV = intravenous.

patients (p = 0.01). Nonoperative patients showed a nonsignificant increased likelihood of having negative culture results (40%) or findings positive for less common organisms (30%) (Fig. 3).

Surgical tissue and blood culture results were available in 60 (77.9%) of 77 cases. Both tests were in agreement in 36 (60%) of these cases. The χ statistic value of 14.2 and p value of 0.03 indicate a significant agreement between swab and blood culture test results. Results for causative organism by tissue and blood culture are shown in Table 7.

Comparisons of the operative and nonoperative cohorts are shown in Table 2. The most common comorbidities included hypertension, previous focus of infection, and diabetes mellitus in, respectively, 44.1%, 32.5%, and 26.0% of the 77 patients in the study. No statistically significant differences were identified between the operative and nonoperative cohorts. With respect to outcome, the degree of symptomatic improvement showed no statistically significant difference between the operative (78.2%) and nonoperative (82.4%) groups (p > 0.99); however, subset analysis identified preoperative weakness as a positive predictor for positive outcome (p = 0.012). There were also no significant differences identified in terms of patient age, location or length of abscess, or causative organism.

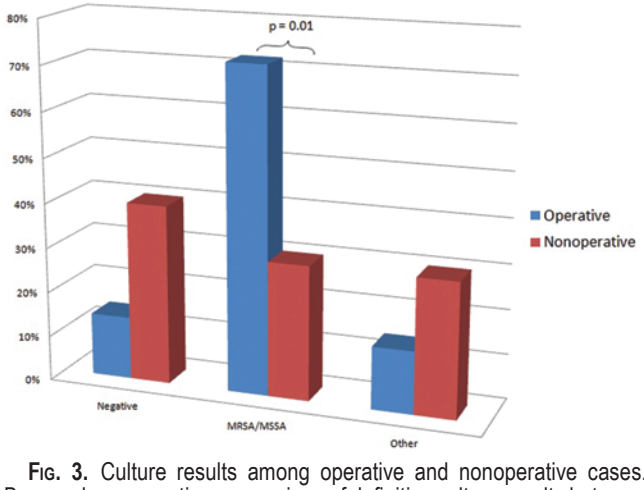

Fig. 3. Culture results among operative and nonoperative cases. Bar graph representing comparison of definitive culture results between operative and nonoperative cases. Results are displayed in terms of percentage of total culture results. MRSA (36.8%) or MSSA (35.1%) was isolated significantly more frequently in operative cases (p = 0.01).

Discussion

Spinal epidural abscess is well established as a potentially devastating illness, with contemporary reports of permanent disability in the range of 15%–27% and mortality of 5%–16%.[5,7,20] The current findings of permanent deficits in 12.5% of patients and a mortality rate of only 1.3% would appear to compare favorably. Improving outcomes going forward will depend vitally upon improving initial recognition, ensuring prompt and appropriate response, and appropriately tailoring treatment to the causative organism and source.

Accurate and timely diagnosis is paramount to the successful management and eventual resolution of SEA. Axial spine pain is reliably reported in 72%–100% of patients with SEA, but as a diagnostic criteria, it leaves much to be desired in terms of specificity.[5,6,13] In 2004, Davis et al.[7] published a case-control series spanning 10 years of emergency room visits resulting in a diagnosis of SEA. In their study, they found that reliance on the "classic triad" of spine pain, fever, and neurological abnormalities for diagnosis positively identified SEA in only 8% of patients on initial visit and 10% at admission, and they advocated strongly for risk stratification of all patients presenting with spine pain. A previous focus of infection, diabetes mellitus, renal disease, or a history of drug abuse could be identified in 66.2% of the patients in our cohort. Davis et al.[7] advocate screening for risk factors demonstrated to be present in 98% of their patients, including diabetes mellitus, intravenous drug use, liver disease, renal failure, indwelling urinary catheters, immunocompromised status, recent invasive spinal procedure, vertebral fracture, or distant site of infection. Based on their results, they recommend additionally screening patients positive for one or more of these comorbidities using elevated erythrocyte sedimentation rate prior to proceeding to focused imaging, a finding supported by several previous studies.[8,12,17,21]

Imaging modalities have improved substantially in the last several decades, making accurate radiographic diagnosis prior to medical or surgical intervention significantly more common. Computed tomography myelography is still considered a highly sensitive method of diagnosis, but it does carry the inherent risk of infectious inoculation of the leptomeninges during CSF access. As recently as 1987, however, this modality was considered the method of choice,[4] though it has largely been supplanted by gadolinium-enhanced MRI.[3,5,6,10,12,17,18,21] Magnetic resonance imaging, in addition to its advantages in diminished invasiveness, can also differentiate abscesses from neoplasms on the basis of differential signal intensity.[5,18] In a recent review, Karikari et al.[14] found that paraplegia or quadriplegia was significantly more common in patients with MRI evidence of SEA localized to the ventral epidural space than in patients with SEA in a dorsal location (p = 0.003). In rare cases of ambiguous MRI findings, the usage of FDG-PET has shown encouraging results in distinguishing degenerative changes from active infection.[10]

Delay in identifying SEA in susceptible patients has been repeatedly associated with poor outcomes. In our series, 38 (66.7%) of 57 patients in the operative cohort underwent decompression within 72 hours of presenta-

TABLE 7: Comparison of causative organism isolated by tissue culture or local swab versus those isolated by blood cultures (n = 60)*

Blood Culture	Tissue Culture or Swab				
	Negative	MRSA	MSSA	Other	Total
negative	8	1	2	0	11
MRSA	6	14	0	0	20
MSSA	8	0	10	0	18
other	7	0	0	4	11
total	29	15	12	4	60

* Shaded cells indicate number of test results that agree; $\chi = 14.2$, $p = 0.03$.

tion and 32 (56.1%) within 24 hours. When compared with the entire cohort, the surgically treated group showed a trend toward greater likelihood of improved outcome; however, this failed to achieve statistical significance ($p = 0.12$). Those patients presenting with focal weakness who underwent decompression were found to be highly likely to show postoperative improvement in neurological condition ($p = 0.012$). In their retrospective review of 153 consecutive cases, Danner and Hartman[4] demonstrated a statistically significant likelihood of less than complete recovery with delays greater than 1.3 ± 1 day. In addition, the authors also recognized that neurological status immediately prior to intervention was the strongest predictor of final outcome ($p < 0.001$), a factor confirmed by many subsequent investigators.[5,6,11,12] It is now almost universally accepted that complete paralysis for longer than 24–36 hours is associated with extremely poor outcome, and it is considered by many as a relative contraindication to operative intervention.[4–6,12,21,27]

Even in cases for which negative predictors have been adjusted and time to intervention has been appropriate, the possibility for poor outcome still looms if appropriate postoperative antibiotic therapy is not initiated. Initial therapy is typically focused on broad-spectrum coverage while final culture results are awaited. It is considered prudent to cover gram-positive flora like MSSA and other *Staphylococcus* species, as these represent 45%–100% of positive cultures, with MRSA accounting for 15%–40%.[1,4–8,11,21,27,28] When our biopsy findings were compared, it was found to be statistically more likely to have a result of *S. aureus* (MRSA or MSSA) in operative culture as opposed to that obtained via percutaneous needle biopsy ($p = 0.01$). Patients were found to have a significantly increased likelihood of negative tissue culture results if intravenous antibiotics were initiated more than 1 day prior to sampling ($p = 0.001$), an effect that has been demonstrated previously.[5] These results make intuitive sense when the typical management of SEA is taken into account. Patients in our cohort progressing to operative management did so, in a majority of cases, within the first 72 hours of hospitalization. The majority of decompression procedures performed for SEA tend to be performed on an emergent basis, normally prior to the institution of antibiotic therapy or achievement of steady-state levels of antibiotics, whereas image-guided confirmatory biopsy is typically scheduled on a more elective basis in medically managed cases. In our series, only 22.2% (2/9) of patients undergoing interventional biopsy for confirmation of causative organisms had their first dose of intravenous antibiotic withheld prior to the procedure.

In most patients started on broad-spectrum, multiagent antibiotic regimens, narrowing of selection of agents is based upon concordance of blood and tissue culture results. In the subset of patients with both cultures available, our data indicate a significant agreement between paired results ($p = 0.03$), indicating the clinical plausibility of tailoring antibiotic regimens based upon blood culture results alone, should tissue cultures fail to grow. We believe these results confirm the findings of several previous studies,[3–5,12] specifically that the necessity of withholding antibiotics immediately prior to surgical decompression for fear of fouling tissue culture results may be unfounded. A comprehensive review published in 2006 by Darouiche et al.[6] demonstrated that concordant bacteremia is detected in about 60% of SEA patients.

In our study, patients who had improved or resolved outcomes following either operative or nonoperative management were significantly younger than those who had poor outcomes (median age 51.1 vs 57.0 years). Similar results were seen by Huang et al.[13] in 2011 when they reviewed their experience with SEA treatment and found a significant association between poor outcome and age > 70 years. Some would argue that the lack of significant difference in outcome between the operative and nonoperative groups would suggest an equivalence of the 2 management strategies; however, a careful review of the literature would argue strongly against such a broad statement. Good nonoperative outcomes have been confirmed in carefully selected patients, although investigations claiming these results consistently include patients with minimal neurological impairment or less-extensive abscesses.[3,6,22–24]

Limitations

Our investigation is limited by its retrospective design, with the expected biases in data collection. Conclusions from this study are also limited by the lack of longer-term follow-up data. The scope of the study was limited in nature, with the characterization of immediate in-hospital recovery being the main focus. Although our results show that surgery did not affect outcomes, we suspect that this may be due to a simple allocation bias. We assume that surgery was offered and performed only in cases where the surgeons observed larger abscesses or

worse neurological presentation. A well-designed prospective trial is sorely needed to improve our understanding of this increasingly important disease entity.

Conclusions

Among 77 patients treated for SEA, age and preoperative weakness were observed to be significantly associated with outcome. Prognosis following SEA is likely dependent on multiple separate yet interrelated factors, including general health of the patient, neurological status at presentation, time to diagnosis, treatment option chosen, and pathogenicity of the causative organism. Our data confirm the utility of peripheral blood cultures as vital to the appropriate selection of antibiotic agents in the treatment of SEA.

We found that decompressive surgery significantly affects outcomes in patients presenting with focal weakness; however, the effect is less clear in other subsets of patients. We strongly suspect that this nonsuperiority may be attributed to allocation biases between patients in the operative and nonoperative cohorts.

Disclosure

None of the authors has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this article.

Author contributions to the study and manuscript preparation include the following. Conception and design: Connor, Chittiboina. Acquisition of data: Connor. Analysis and interpretation of data: Connor, Chittiboina. Drafting the article: Connor, Chittiboina. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Nanda. Statistical analysis: Connor, Chittiboina. Study supervision: Nanda.

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