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Review article

Holospinal epidural abscesses – Institutional experience

Kelly J. Bridges, Khoi D. Than *

Department of Neurological Surgery, Oregon Health & Science University, Portland, OR, United States

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ABSTRACT

Purpose: The authors present a holospinal epidural abscesses (HEA) case series and a single institution's experience with varied surgical approaches and outcomes.
Methods: Medical records were queried and reviewed (6 years) for patients with a spinal abscess diagnosis; HEA were selected. Medical history, comorbidities, blood and epidural pathogens, presentation symptoms, abscess location, presence of mass effect, surgical procedures, treatment regimens, and neurological outcomes were collected.
Results: Eight patients with HEA were treated; all underwent surgery. In the index procedure, one (12.5%) underwent laminectomy of the entire spinal column, four (50%) focal laminectomies at the area of mass effect, and three (37.5%) skip laminectomies. Of the four patients who initially had focal laminectomies, three (75%) required additional operations for abscess evacuation in other spine regions. Average number of laminectomies per patient was 8.6. Neurologically, 50% of patients improved, 37.5% remained stable, and 12.5% worsened. There was no difference in outcome between patients who underwent skip versus panspinal laminectomies. No differences in outcomes were noted in timing from presentation to surgery (median 5.3 h), location of mass effect, dorsal versus ventral abscesses, or initial symptoms. Of the four patients who had cervical laminectomy without fusion, two developed post-laminectomy kyphosis requiring fusion.
Conclusion: Cervical instability occurred in half the patients who underwent cervical laminectomies without fusion, and there were no adverse outcomes in the patients who were fused in the setting of infection. For lower cervical abscess, upper thoracic laminectomy with catheter irrigation may be sufficient for decompression, minimizing risk of future instability.

1. Introduction

Spinal epidural abscesses are rare, accounting for 1 in 10,000 hospital cases [13,17,39,42,43,46]. They can result in rapid neurologic deterioration with permanent deficits and mortality [21,42,43,46]. Even more infrequent are holospinal epidural abscesses (HEA), affecting the cervical, thoracic, and lumbar spine. Other terms include panspinal, panregional, and multiregional spinal epidural abscesses. HEAs can affect people of all ages, but are more frequently seen in the fifth and seventh decades of life [18]. Risk factors include prior interventions of the vertebral canal, diabetes mellitus, intravenous drug use, pregnancy, and any form of immunosuppression, malignancy, steroid use, cirrhosis, Crohn's disease, and chronic renal disease [14,17,18,42]. Psoas abscesses and other soft tissue infections have also been seen in the setting of HEA [42].

Patients commonly present with a triad of back pain, fever, and neurological deficits [14,21,24,34,42,43,46]. They may additionally complain of radicular symptoms and can have myelopathic findings on examination [21,39,42]. Blood work will often reveal marked leukocytosis as well as elevations in inflammatory markers [21,39,41]. Meanwhile, blood cultures are essential in early pathogen identification [42].

Staphylococcus aureus is the most common organism identified in HEAs, accounting for approximately two-thirds of cases [17,39,42,43]. Less common pathogens include coagulase-negative staphylococci and gram-negative bacteria [43]. Spinal epidural abscesses in general are thought to be spread via a hematogenous route or by direct extension from localized areas, such as osteomyelitis [14,43].

Gram stains of cerebrospinal fluid (CSF) have been negative in over 75% of cases of spinal epidural abscesses, and lumbar puncture should be avoided if epidural abscess is suspected, given the risk of inoculating the CSF with epidural pathogens [43]. Computed

* Corresponding author at: Department of Neurological Surgery, Oregon Health & Science University, Mail Code CH8N, 3303 SW Bond Avenue, Portland, OR 97239, United States.

E-mail address: thank@ohsu.edu (K.D. Than).

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Table 1
Location of spinal epidural abscesses in the 41 patients treated at OHSU from 2011 to 2016.

Location	Number of patients (%)
Cervical	8 (20%)
Thoracic	8 (20%)
Lumbar	11 (27%)
Cervico-thoracic	3 (7%)
Thoraco-lumbar	3 (7%)
Holospinal	8 (20%)

tomography (CT) is unreliable, and diagnosis should be made with magnetic resonance imaging (MRI) of the entire neural axis both with and without contrast [14,17,21,42]. Intracranial purulence associated with HEA is rare, as dural leaflets around the foramen magnum help prevent rostral spread of infection [32]. However, meningitis has been reported, albeit infrequently [44].

HEA is a potentially devastating disease requiring prompt diagnosis and treatment, given its risk of catastrophic neurological consequences [13,14,17,21,22,24]. However, no consensus has been

Table 2
Six-year holospinal epidural abscess data at a single institution.

	n (%)
Total patients (n)	8
Total related spine surgeries (n)	13
Sex	
Male	6 (75)
Female	2 (25)
Average Age (range 27–70 years)	50 years; median 55 years
Average BMI	35.3
Tobacco use	4 (50)
Drug use	3 (37.5)
Comorbidities	
Hepatitis C	2 (25)
Diabetes Mellitus 2	3 (37.5)
Concurrent infections in other location (excluding bacteremia)	4 (50)
Pre-operative blood cultures	
Negative	1 (12.5)
Positive, MSSA	5 (62.5)
Positive, MRSA	2 (25)
Organism identified within spinal epidural space	
MSSA	6 (75)
MRSA	2 (25)
Symptoms at presentation	
Back Pain	6 (75)
Subjective weakness (diffuse or focal)	6 (75)
Progressively worsening symptoms	5 (62.5)
Urinary retention/incontinence	5 (62.5)
Recent fall	3
Neurological exam (ASIA score) at presentation	
ASIA A	2 (25)
ASIA D	5 (62.5)
ASIA E	1 (12.5)
Overall outcomes in neurological exam (ASIA Score)	
Improved	4 (50)
Worsened	1 (12.5)
Unchanged	3 (37.5)
Average WBC on admission (reference range; 4.40–11.00 K/cu mm)	18.9
Average ESR on admission (reference range; 0–20 mm/hr)	61.5
Average CRP on admission (reference range; $\leq$5 mg/dL)	183.2
Echocardiogram findings negative for cardioembolic source	8 (100)
Location of abscess (ventral vs dorsal)*	
Ventral	5 (62.5)
Dorsal	8 (100)
Circumferential	4 (50)
Mass effect (cervical vs thoracic vs lumbar)**	
Cervical	7 (87.5)
Thoracic	4 (50)
Lumbar	8 (100)
Surgical Procedure	
C2-S1 laminectomies	1 (12.5)
Skip laminectomies	6 (75)
Focal laminectomies at area of mass effect	1 (12.5)
Patients with staged procedures***	4 (50)
Patients who received decompressions of cervical, thoracic, and lumbar spine	5 (62.5)
Average number of levels laminectomized/patient	8.6
Patients who underwent instrumented fusion (n)	2 (25)
Anterior cervical discectomy and fusion, C2/3	1
Posterior cervical fusion, C2-7	1

(*continued on next page*)

Table 2 (*continued*)

	n (%)
Median time from presentation to incision (hours)	5.3
Median operative time (hours)	2.9
Median EBL (mL)	250
Patients receiving intraoperative transfusions	3 (37.5)
Surgical Complications	None reported
Post-op destination = ICU	7 (87.5)
Average number surgical drains/procedure (n)	2.08
Average maximum duration of surgical drain (days)	4.3
Average length of hospital stay (days)	22.9 days
Discharge location	
Skilled nursing facility	4 (50)
Inpatient rehabilitation center	1 (12.5)
Home	2 (25)
Deceased	1 (12.5)
Number of Surgeons (n)	6
Orthopedic surgery	2
Neurological surgery	4
Duration to last follow-up (weeks; range 1–118 weeks)	18.5 (median); 34.25 (mean)

ED = Emergency Department; MSSA = Methicillin Sensitive *Staphylococcus aureus*; MRSA = Methicillin Resistant *Staphylococcus aureus;* ASIA = American Spine Injury Association scale (A-E); WBC = White Blood Cell; ESR = Erythrocyte Sedimentation Rate; CRP = C-Reactive Protein; EBL = Estimated Blood Loss; BP = Blood Pressure; ICU = Intensive Care Unit.

* Some patients had both dorsal & ventral components, as well as circumferential abscess, thus sum > 8.

** Some patients had multiple levels with mass effect, thus sum > 8.

*** Number of patients who underwent spinal procedures performed on different days; all within same hospital admission.

made on the specific treatment of HEA [29,46]. To date, literature includes isolated case reports of one to two patients. Here, we present the largest series of cases, to our knowledge, and a single institution's experience including 8 cases of HEA in a 6-year period. Varied surgical approaches and outcomes, as well as many other factors, are assessed.

2. Methods

Following Institutional Review Board (IRB) approval, departmental medical records were queried for all patients within the past 6 years (2011–2016), with diagnosis codes for spinal abscess (ICD-9 code 324 and ICD-10 code G06). This yielded 46 patients in total – 41 with epidural abscesses and 5 with isolated osteomyelitis and/or discitis. (Table 1) Charts were individually reviewed to find patients specifically with HEAs, totaling 8 patients, treated by either the neurological surgery or orthopedic surgery teams. Information was then collected on medical history, comorbidities, pre-operative blood cultures, epidural pathogens, symptoms at presentation, abscess location and presence of mass effect, surgical procedures, treatment regimens, and neurological outcomes, including need for additional procedures.

3. Results

A total of 8 patients with HEA were treated at our institution over the past 6 years. (Tables 2 and 3). Age ranged from 27 to 70 years (mean 50 years), and patients were predominantly male (62.5%). Intravenous drug use was endorsed in 37.5% of patients. Medical comorbidities included diabetes mellitus (37.5%) and hepatitis C (25%). Half of the patients had infections elsewhere in their body. Pre-operative blood cultures were positive in 87.5% (7/8) of patients, however all echocardiograms were negative for cardioembolic source. Laboratory workup revealed an average white blood cell (WBC) count of 18.9 K/cu mm. Average erythrocyte sedimentation rate (ESR) was 61.5 mm/hr (reference range 0–20), and average C-reactive protein (CRP) was 183.2 mg/dL (reference range $\leq$5). Symptoms at presentation included back pain (75%), subjective weakness (75%), bladder dysfunction (62.5%), and a recent fall (37.5%). All but one patient had detectable neurological deficits, and all had HEAs with mass effect on MRI. Six patients (75%) additionally had evidence of osteomyelitis, discitis, or septic arthritis.

All 8 patients were treated surgically, and the types of procedures varied. One patient (12.5%) underwent a radical laminectomy of the entire spinal column. Three patients (37.5%) underwent skip laminectomies at the index procedure. The remaining four patients (50%) initially had focal laminectomies at the area of mass effect, however three of them required reoperation at other levels due to worsening neurologic deficit, persistent bacteremia, or increasing abscess on imaging.

Overall, six patients (75%) underwent skip laminectomies. This involved surgical decompression in the cervical, thoracic, and lumbar spines for four patients (50%). The other two patients (25%) had skip laminectomies involving the upper and lower thoracic spine as well as the lumbar spine (Fig. 1). One patient (12.5%) had isolated cervical spine decompression. The average number of levels laminectomized was 8.6 per patient. None of the patients had discectomies nor corpectomies for surgical treatment of their osteomyelitis or discitis. Median operative time was 2.9 h, and median estimated blood loss (EBL) was 250 mL. There were no surgical complications reported, and 87.5% (7/8) of patients went to the intensive care unit (ICU) post-operatively. Cultures were positive for methicillin sensitive *Staphylococcus aureus* (MSSA) in 75% (6/8) of patients and methicillin resistant *S. aureus* (MRSA) in 25% (2/8) of patients. None of the patients received peri-operative steroids, and blood pressure augmentation was maintained for one patient (mean arterial pressure goal >80) who was quadriplegic and had T2 hyperintensity within the upper cervical spinal cord.

The average length of hospital stay was 23 days. Patients required treatment for distant infections, sepsis, pulmonary emboli, and urinary retention. Furthermore, discharges were delayed in some of these patients due to lack of insurance and history of intravenous drug use requiring special orchestration of outpatient intravenous antibiotics. Average hospital fees were $224,050.61. Discharge locations included skilled nursing facilities for 50% (4/8) of patients, inpatient rehabilitation for 12.5% (1/8) of patients, and home for 25% (2/8) of patients. One patient had multiple medical comorbidities prior to admission and was quadriplegic pre- and post-operatively. He opted for comfort care measures and deceased during his hospitalization.

Table 3
Individual patient characteristics.

Pt	Age (years)	Sex	Location of HEA Abscess	Location of Mass Effect	Other MRI Findings	Surgical Procedure (s)	Total # Surgeries	Instrumentation Used	Organism	Exam at Presentation	Post-Op Exam	Exam at Last Follow-Up	Time to Last Follow-Up (weeks)	Other
1	64	M	Dorsal and Ventral	C7-T2; Left L4-5 lateral recess & foramen	Multilevel cervical osteomyelitis; T11/12 discitis	C3-7 Lami; R C4/5, C5/6 Foraminotomies	1	No	MSSA	4–/5 R deltoid (ASIA D)	4–/5 R deltoid; 4+/5 L deltoid (ASIA D)	Intact (ASIA E)	118	Post-operative cervical kyphosis
2	66	M	Dorsal	C4-C5, L5-S1	C4/5 and C5/6 osteomyelitis and discitis	C2-C6 Lami, C2-7 Posterior Fusion; T9-L1 Lami; L2-L5 Lami	3	Yes	MRSA	2–3/5 proximal BUE; 1/5 distal BUE; 0/5 BLE (C7 ASIA A)	1/5 deltoids (C5 ASIA A)	4–/5 BLEs (ASIA D)	60	
3	28	F	Dorsal	C2-L5	None	C3-C6 & Mid-Thoracic Lami; L4 Lami	2	No	MSSA	5/5 strength; decreased perineal sensation (ASIA E)	Intact (ASIA E)	4/5 Bilateral grip (ASIA D)	13	Post-operative C5/6 subluxation with C6 perched facets
4	27	M	Dorsal and Ventral	C3-T12, L3-S1	L4/5 discitis and osteomyelitis; multiple soft tissue paraspinal abscesses	C2-S1 Lami	1	No	MRSA	4/5 R hip flexion; otherwise 5/5 throughout (ASIA D)	Intact (ASIA E)	Intact (ASIA E)	44	
5	70	M	Dorsal and Ventral	C3-C4, L2-L3	C4/5 discitis; L3/4, L4/5 discitis and osteomyelitis	C3-C5 Lami; T12 & L2 Lami	2	No	MSSA	Initially intact; delayed 0/5 R deltoid, 4/5 BUEs, 5/5 BLEs (ASIA D)	4–/5 R deltoid; otherwise 5/5 throughout (ASIA D)	3/5 R deltoid (ASIA D)	24	
6	55	M	Dorsal and Ventral	C4-S2	None	T3, T8, L2 Lami	1	No	MSSA	4+/5 BUE; 4+/5 dorsi/plantar flexion; otherwise 5/5 throughout (ASIA D)	4 + Bilateral knee flexion; otherwise 5/5 throughout (ASIA D)	Intact (ASIA E)	7	
7	58	M	Dorsal and Ventral	C2, T11-S2	Right C2/3 septic facet; Right psoas abscess	C2, T8, L5 Lami; C2/3 ACDF	2	Yes (Anterior)	MSSA	0/5 throughout (ASIA A)	0/5 throughout (ASIA A)	0/5 throughout (ASIA A)	1	Withdrew care (multiple medical comorbidities); deceased 5 days post-op
8	33	F	Dorsal	T2-T9, L3-S1	L1/2 osteomyelitis; Multiple paraspinal and facet abscesses (most prominent at T5/6 and L4/5); Left psoas abscess	T4, T8, L4 Lami	1	No	MSSA	4–5/5 throughout (ASIA D)	4/5 R deltoid and tricep; 4/5 bilateral hip flexion (ASIA D)	4–/5 L hip flexion and knee flexion/ extension (ASIA D)	7	

Pt = patient #; M = Male; F = Female; HEA = Holospinal Epidural Abscess; Lami = Laminectomies; ACDF = Anterior Cervical Discectomy and Fusion; MRSA = Methicillin Resistant Staphylococcus aureus; MSSA = Methicillin Sensitive Staphylococcus aureus; ASIA = American Spinal Injury Association Scale (A-E).

Follow-up time ranged from 1 to 118 weeks, with average follow-up of 34 weeks. When graded by ASIA score, 50% (4/8) of patients improved, 37.5% (3/8) remained stable, and 12.5% (1/8) worsened. There was no difference in outcome appreciated between patients who underwent skip laminectomies versus pan-spinal laminectomies. Furthermore, no difference in outcome was noted in timing from presentation to surgery (median 5.3 h, mean 7.8 h), location of mass effect, dorsal versus ventral abscess location, or symptoms at presentation. Of the six patients who had cervical laminectomies, two had fusions at the time of decompression. Of the remaining four patients with cervical decompression, two (50%) developed post-operative kyphosis warranting surgical correction. One patient had undergone C7-T2 decompression, and subsequently developed 40 degrees post-operative kyphosis noted 21 months after surgery. The other patient underwent C3-C6 laminectomies, and their 3-month post-operative X-ray revealed C5-C6 subluxation with C6 perched facets. At that time, she was noted to have decreased bilateral grip strength. This was the only patient in the series who had a worsened neurological outcome post-operatively (ASIA E to ASIA D) (Fig. 2).

4. Discussion

4.1. Epidemiology and etiology

In our series, *S. aureus* was the cultured pathogen in all cases (MSSA in 75% and MRSA in 25%). Smith et al., reviewed 19 case reports and found 36.8% (7) of patients with psoas abscess and other soft-tissue infections, [42] while our cases series of 8 patients revealed 50% (4) with concurrent infections elsewhere in the body. Studies have shown that spinal cord injury can occur from both mechanical compression as well as cord infarction secondary to arteritis, venous thrombosis, or septic thrombophlebitis [3,5,11,12,35,38,39,42].

4.2. Presentation and work-up

Blood cultures are essential in early pathogen identification and have been positive in up to 60% of reported cases [27,37,42]. We found that 87.5% (7/8) of our patients with HEA had positive blood cultures at the time of presentation. Interestingly, endocarditis is rarely identified in cases of HEA. In Smith et al.'s, review of 19 cases, only one patient had documented endocarditis [42]. In our series of 8 patients, none were found to have a cardioembolic source for their infection.

4.3. Treatment

Neurological deterioration can occur rapidly and even result in death [40]. Simpson et al., reported their experience with a patient who rapidly became quadriplegic and suffered cardiopulmonary arrest, passing away before receiving operative intervention [40]. In our series of 8 patients, 1 (12.5%) had further neurological decline after presentation, and symptoms did not fully improve post-operatively. That being said, no consensus has been made on the specific treatment of HEA [29,46].

4.4. Role for non-operative treatment

While many authors suggest surgical drainage, together with systemic antibiotics, as the main treatment of choice, others have reported successful treatment of HEAs non-operatively with antibiotics, given there is early clinical improvement [3,13,17,24,25,30,42,43,45,46]. O'Brien et al., presented a 71-year-old man with 4/5 strength in all extremities found to have a ventral HEA, which they treated conservatively. He remained neurologically stable, and an MRI 2 months later demonstrated near-complete resolution of the abscess [25]. Killen et al., reported their case of a 77-year-old man who had a delayed diagnosis of HEA, 48 h after presentation for medical attention. He had 4/5 motor power in all extremities and was treated non-operatively with intravenous antibiotics. His neurological exam gradually began to improve two weeks later, and by four weeks, MRI showed complete resolution of abscess, inflammatory markers were decreased, and he was noted to have full strength in all extremities [17]. Van Bergen et al., treated a 50-year-old man with a dorsal HEA felt to have numerous septations. He was neurologically intact and treated conservatively with antibiotics. Five weeks later, MRI revealed mild fibrosis surrounding the spinal cord and a small residual abscess at T5-T6 [45]. Lin et al., reported a case of a 41-year-old man who was meningitic and quadriplegic requiring mechanical ventilation, treated with intravenous antibiotics with "significant improvement in neurologic deficit" [24]. Ghosh et al., reported their

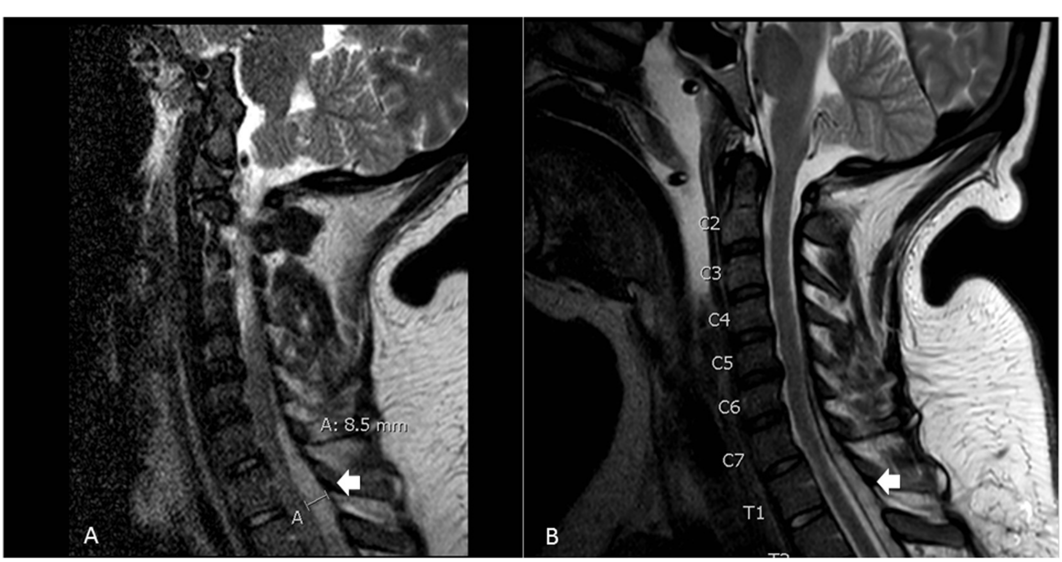

Fig. 1. Pre-operative (A) and post-operative (B) cervical spine MRIs are shown for a patient with HEA who only underwent thoracic and lumbar laminectomies. A T4 laminectomy with catheter irrigation achieved noticeably decreased mass effect in the lower cervical spine (arrows), while sparing the cervico-thoracic junction.

experience with a 7-month-old girl with right lower extremity weakness treated non-surgically with intravenous antibiotics, and she was noted to be neurologically intact at her three-month follow-up [13].

4.5. Role for surgical management

Many authors advocate for surgical intervention in any patient with neurological compromise [8]. Others recommend surgical intervention for acutely deteriorating patients, while others encourage aggressive surgical intervention of HEA even if there are normal findings on neurological examination [42]. Preoperative neurological status has been found to be the most important predictor of final neurological outcome, thus it is recommended that surgical intervention be performed as quickly as possible in the setting of neurological compromise [14,16,43]. That being said, Gorchynski et al., reported a case of a 33-year-old man with paralysis lasting longer than 24 h who recovered some function (3/5 motor power) by 6 months after surgical intervention [14]. Riaz et al., reported their experience with a 56-year-old man with quadriparesis for 24 h who progressively improved post-operatively and could walk with minimal support 4 months after surgery [31]. Others have reported neurological improvement up to 13 months after presentation [21]. Radiographic signs of cord compression or inflammation are red flags, warranting further consideration for early surgical evacuation regardless of neurological

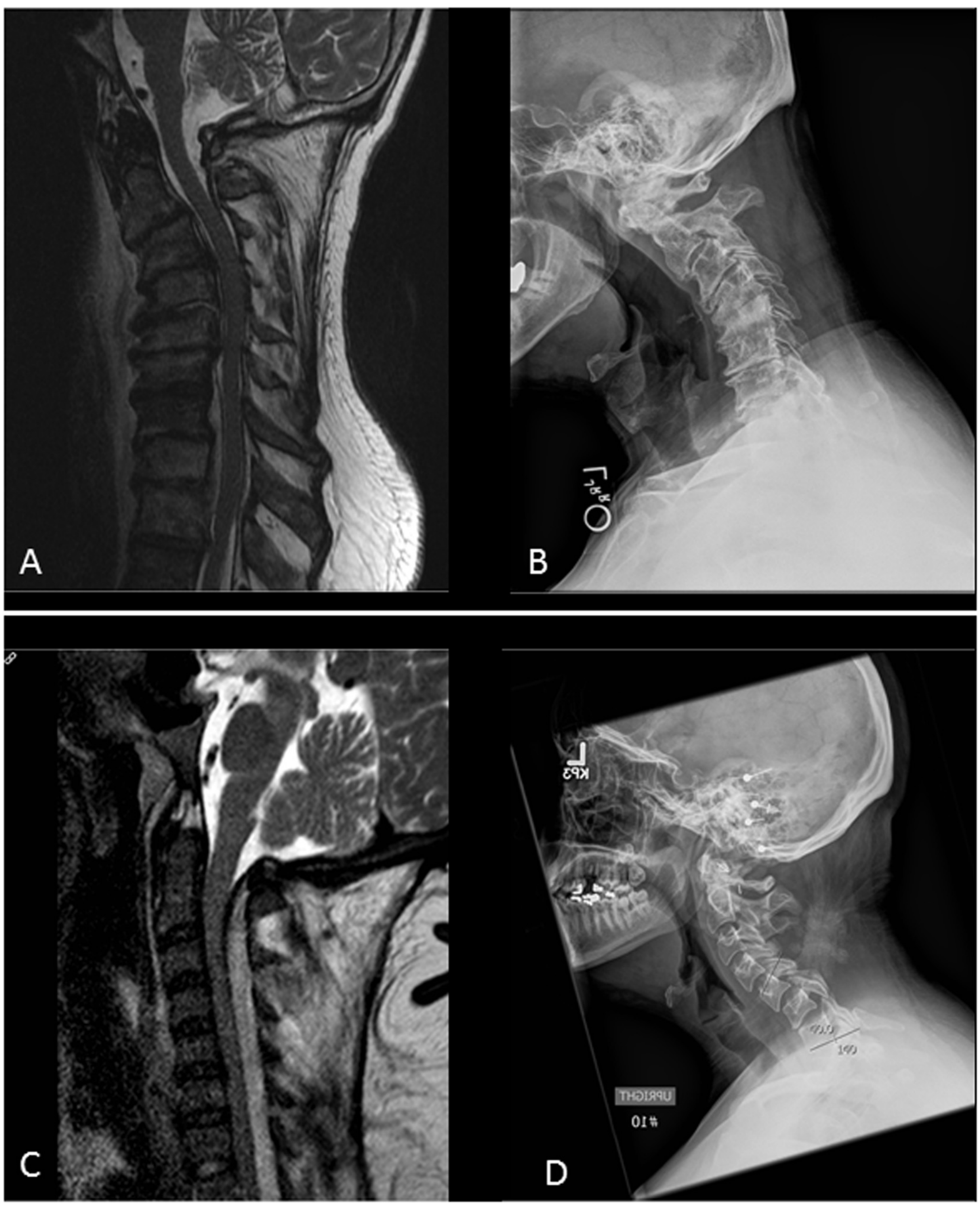

Fig. 2. Imaging demonstrates cervical kyphosis and instability following cervical laminectomies without fusion. Figure A reveals a pre-operative MRI of a patient who underwent C3-C7 laminectomies with right C4-C5 and C5-C6 foraminotomies for decompression of an HEA. A lateral cervical spine X-ray (B) 21 months post-operatively reveals pronounced cervical kyphosis. Figure C reveals a pre-operative MRI of a different patient who underwent C3-C6 laminectomies for evacuation of an HEA. A lateral cervical spine X-ray (D) 3 months post-operatively reveals C5-C6 subluxation with C6 perched facets and 40° kyphosis of the lower cervical spine.

status [42]. In our series of 8 patients, all but one presented with neurological compromise, all had mass effect on the spinal cord, and all received surgical intervention.

4.6. Extent of surgery

Options for surgical intervention include focal decompression over the region of significant mass effect, segmental (skip) laminectomies with catheter irrigation, and radical laminectomy of the entire spinal column [9,21,23,33,41,43]. Panspinal decompression predisposes patients to complications such as increased blood loss, cardiac and respiratory difficulties, prolonged post-operative pain, progressive kyphotic deformity, and instability [29,43,46]. On the other hand, skip laminectomies maintain the posterior tension band, and care can be taken to avoid surgical decompression of the cervicothoracic, thoracolumbar, and lumbosacral junctions to prevent destabilization [42]. Catheter irrigation and aspiration of several levels appears safe and allows surgeons to avoid these junctions while improving evacuation (Fig. 1) [42]. Riaz et al., performed skip laminectomies on a 56-year-old gentleman with quadriparesis, and he was able to walk with minimal support 4 months post-operatively [31]. Hwang et al., performed skip laminectomies via unilateral approaches, alternating sides, on a 51-year-old patient with progressive lower extremity weakness and found success [15]. Shoakazemi et al., performed skip laminectomies in a 44-year-old gentleman who had rapidly developed quadriplegia, and he walked independently 2 months after rehabilitation [39]. Smith and Kavar, discuss a 25-year-old gentleman who presented with profound quadriparesis found to have a predominantly dorsal HEA. He underwent skip laminectomies, after which an MRI demonstrated near complete removal of the abscess. He required repeat drainage of an accumulating cervical epidural abscess and, at 2 months, had recovered to have antigravity power in his upper extremities but remained diplegic in his lower extremities [41].

In our series, 12.5% (1/8) of patients had radical panspinal laminectomies, and 75% (6/8) of patients ultimately had segmental laminectomies. There was no difference in outcomes between skip laminectomies and panspinal laminectomies for HEA, suggesting that skip laminectomies are equally effective in achieving adequate spinal decompression, while minimizing risks associated with radical laminectomies of the entire spinal column.

Of importance, 75% (3/4) of the patients who initially underwent focal decompressions required subsequent return to the operating room for decompression at different levels of the spine due to worsening examination, persistent bacteremia, and/or increasing spinal abscess. Only one patient underwent focal decompression at the area of most significant mass effect and did not require return to the operating room. This experience has been shared with other surgeons as well. Smith et al., report a case of a 41-year-old man initially full strength in all extremities who underwent an L3 laminectomy for evacuation of an HEA that was worst at the thoracolumbar junction. Six days later, the patient became quadriparetic and was noted to have an increased ventral collection at the craniocervical junction warranting emergent C1-C2 laminectomies for decompression. At 11 months post operatively, the patient was ambulating with assistance [42]. Lau et al., share their experience with a 46-year-old man with paraparesis and incontinence who underwent L2-L3 posterior decompression, but developed upper extremity weakness 2–3 days later requiring

Fig. 3. An MRI reveals predominantly dorsal HEA with T2 signal that is hyperintense relative to surrounding tissues (A-C). Post-gadolinium imaging reveals rim enhancement with a hypointense core, most consistent with liquid pus (D-F).

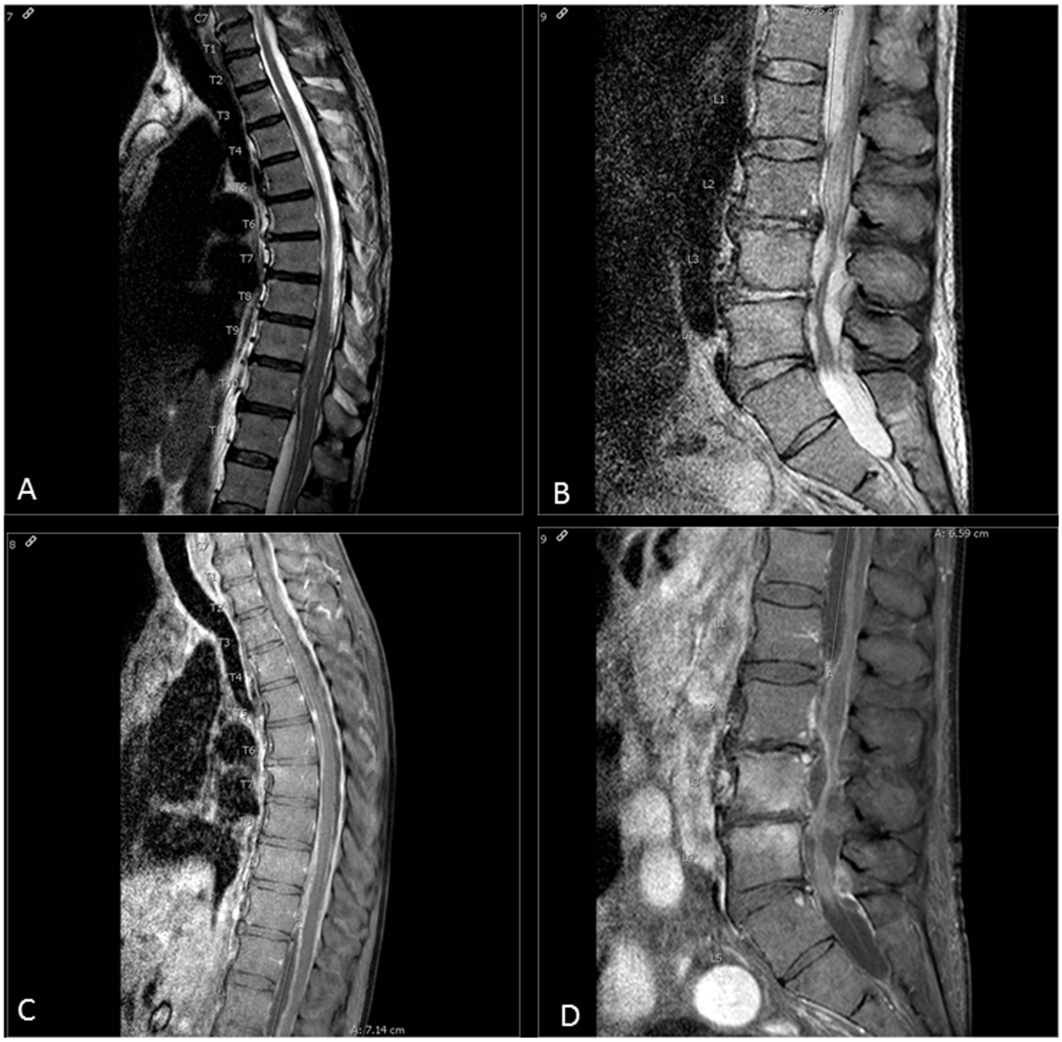

Fig. 4. Pre-operative MRI with T2 (A & B) and post-gadolinium (C & D) images demonstrate a dorsal HEA with a large ventral component of liquid pus from T10 to the L1/2 interspace. This was treated with C3-5, T12, and L2 laminectomies with good outcome.

Fig. 5. Pre-operative (A) and post-operative (B) cervical spine MRIs, T2 weighted, in a patient with multiple medical comorbidities who presented with HEA in the ventral cervical and thoracic spine as well as dorsal thoracic and lumbar spine. Post-operative MRI following C2, T8, and L5 laminectomies reveals an increase in ventral purulence in the upper cervical spine with associated elevation in mass effect and spinal cord edema.

C3-C6 and T6-T9 laminectomies. One month post-operatively, the patient had full strength in his upper extremities and was antigravity in his lower extremities [21]. Our experience, as well as that of others, suggests that decompressing the cervical, thoracic, and lumbar spines in the first operation would be beneficial in preventing neurological decline and reoperation.

4.7. Approach for ventral versus dorsal collections

Distinguishing phlegmon from liquid pus is essential when determining a surgical approach [42]. Phlegmon will tend to be hyperintense on T2-weighted images while homogenously enhancing on T1 post-gadolinium sequences. Meanwhile, liquid pus tends to be rim enhancing with a hypointense core (Fig. 3) [2,10,20,28,39,42].

HEA can involve both the ventral and dorsal epidural space. Review of the literature reveals that traditionally a posterior approach with irrigation has been successful for the treatment of HEA [42]. This holds true in our experience as well (Fig. 4). In our series, 62.5% (5/8) of patients had a ventral component to their HEA, and only one patient underwent an anterior approach for decompression. That being said, if the ventral collection is extensive with significant cord compression, if there is kyphotic deformity, or if the compression is due to ventrally located phlegmon above the level of the conus, a posterior approach may prove insufficient [42]. The one patient in our series who required ventral decompression initially presented with quadriplegia and both dorsal and ventral HEA. He underwent skip laminectomies of the cervical, thoracic, and lumbar spine, however post-operative imaging revealed increased ventral purulence as well as more prominent T2-signal in the upper cervical spinal cord (Fig. 5). This patient subsequently underwent a C2-C3 anterior cervical discectomy and fusion for further decompression. In our review of the literature, there is only one case reported where an anterior approach was required. Lau et al., treated a 50-year-old man with a ventral HEA, discitis, and osteomyelitis by performing an aggressive transoral odontoidectomy followed by posterior fusion, after which the patient had "significant" recovery in his upper extremity strength at 13 months post-operatively [21].

4.8. Use of instrumentation

In our series, 75% (6/8) of patients underwent cervical laminectomies, two of whom had fusion at the time of decompression with no adverse outcomes. Meanwhile, 50% (2/4) of the patients without fusion developed progressive cervical kyphosis or instability warranting instrumented fusion (Fig. 2). The only patient in our series who had a worsened neurological outcome post-operatively was a 28-year-old, neurologically intact, female with HEA who underwent skip laminectomies, including C3-C6 levels, without fusion. She developed bilateral grip weakness three months post-operatively, and X-rays revealed C5-C6 subluxation with C6 perched facets and 40° kyphosis of the lower cervical spine. Given this, one may consider performing instrumented fusion up front in these cases.

Many surgeons have supported the use of interbody arthrodesis as well as instrumentation in the setting of active infection, should it be required for stabilization [2,6,19,36,42]. Lau et al., described their algorithm for placement of instrumentation when they felt hardware was needed in the setting of infection [21]. The authors describe placing implants at the time of decompression in the absence of obvious liquid purulent material. However, if gross purulent material was present, the patient would undergo a second staged procedure for instrumentation after two weeks of antibiotic therapy. Titanium implants were preferred over stainless steel implants given titanium's decreased risk of biofilm formation [4,21].

In lieu of performing a cervical laminectomy for decompression, one may consider performing an upper thoracic laminectomy with catheter irrigation of a lower cervical abscess without risk of subsequent instability. Two of the patients in our series (25%) underwent upper thoracic laminectomies (T3 and T4) with successful decompression of the cervical spine without need for further laminectomy or fusion (Fig. 1).

4.9. Medical management

Regardless of whether patients with HEA undergo surgical intervention, other needs for optimal medical management may exist but have not yet been studied in the setting of HEA, given its extremely rare incidence. In our series, 87.5% (7/8) patients were admitted to the Neuroscience ICU or Medical ICU for optimization of care. The one patient who went to the neurosurgical ward post-operatively was neurologically intact pre- and post-operatively as well as hemodynamically stable.

The Infectious Disease team was involved in all of the cases we report, and antibiotic regimens varied based on organism sensitivities as well as patient allergies, medical comorbidities, compliance, and adverse reactions. All patients had *S. aureus* infections (75% MSSA, 25% MRSA). Antibiotics included cefepime, cefazolin, clindamycin, daptomycin, doxycycline, nafcillin, vancomycin, ceftriaxone, augmentin, and cefuroxime. Antibiotic treatment typically involved at least 6 weeks of intravenous therapy followed by at least 6 additional weeks of oral therapy. Regimens typically lasted a minimum of 3–5 months.

In our series, none of the patient received steroids. In reference to nonspecific neural infection and bacterial meningitis, the literature supports the use of steroids to decrease inflammation and prevent morbidity [1,7,26]. However, this has not been addressed specifically for HEA. Smith et al. suggest that the potential benefit of steroids outweighs the risks in the setting of an acutely deteriorating patient [42].

Blood pressure augmentation has also been poorly studied in the HEA population. Smith et al., discuss the use of blood pressure augmentation to reduce morbidity in the trauma setting and argue in its favor in the setting of declining patients with HEA as well [42]. In our series, blood pressure augmentation, with mean arterial pressure (MAP) >80, was encouraged in one patient who had presented with quadriplegia and upper cervical spinal cord edema. Three other patients were hypotensive peri-operatively requiring pressors post-operatively to maintain MAP goals >65. The remaining 50% (4/8) of patients had no specified MAP goals and did not require pressors to maintain normotension.

5. Conclusion

Upon review of a relatively large series of HEA at a single institution, data demonstrates there is no difference in outcome between skip laminectomies versus panspinal laminectomies, suggesting that a more conservative approach is equally as effective. Most patients ultimately required their cervical, thoracic, and lumbar spines be decompressed, suggesting that doing this in the first operation would be beneficial in minimizing returns to the operating room, decreasing persistent bacteremia, and lessening risk of progressive neurological compromise. Cervical instability occurred in half the patients who underwent cervical laminectomies without fusion, and there were no adverse outcomes in the patients who were fused in the setting of infection. Thus, one may consider performing instrumented fusion up front in these cases. For lower cervical abscess, an alternative option to cervical laminectomy, and subsequent fusion, is to perform an upper thoracic laminectomy with catheter irrigation. Doing this in lieu of a cervical laminectomy may minimize risk of subsequent instability while adequately achieving evacuation of the cervical abscess.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jocn.2017.10.057.

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