

Clinical Study

Outcomes of multilevel vertebrectomy for spondylodiscitis

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Abstract

BACKGROUND CONTEXT: The incidence of pyogenic vertebral osteomyelitis (PVO) continues to increase in the United States, highlighting the need to recognize unique challenges presented by these cases and develop effective methods of surgical management. To date, no prior research has focused on the outcomes of PVO requiring two or more contiguous corpectomies.

PURPOSE: To describe our experience in the operative management of PVO in 56 consecutive patients who underwent multilevel corpectomies (≥ 2 vertebral bodies) via a combined approach.

STUDY DESIGN/SETTING: Single institution retrospective cohort review between January 2002 and December 2015. All patients had been treated at an academic tertiary referral center by one of two fellowship-trained orthopedic spine surgeons.

PATIENT SAMPLE: Patient records were cross-referenced with International Classification of Diseases osteomyelitis codes and paravertebral abscess code. Inclusion criteria for the study were patients within the cohort who had adequate medical records for review, a minimum patient age of 18 years, active vertebral osteomyelitis as an indication for surgical intervention, a minimum of 1-year radiographic follow-up, and surgical intervention that included at least two complete vertebral corpectomies. Subsequently, 56 patients met the inclusion criteria and were reviewed for this retrospective analysis.

OUTCOME MEASURES: Outcomes of interest were readmission and reoperation rates related to treatment of PVO, 30-day and 1-year mortality rates, radiographic outcomes, perioperative complications, infection control, and length of stay.

METHODS: After obtaining approval from the Institutional Review Board, retrospective review was performed on records of all adults with PVO refractory to standard nonoperative treatment who underwent complete corpectomy of two or more contiguous vertebrae at a single institution between January 2002 and December 2015. This study was not funded, and no potential conflict of interest-associated biases were present.

RESULTS: Fifty-six patients were identified (63% men; mean age 56.8 years; mean radiographic follow-up 2.8 years). Median length of stay was 13 days with nearly half readmitted (47%) after a

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median of 222.5 days after surgery. Twelve (22%) posterior revisions were required after a median 54 days for infection, painful or failed hardware, proximal junction kyphosis, adjacent level disease, or extension of the fusion. Thirty-day and 1-year mortality rates were 7.14% and 19.6%, respectively, with an infectious etiology as the most common cause of death.

CONCLUSIONS: Multilevel vertebral corpectomy for treatment of refractory vertebral osteomyelitis is associated with relatively high rates of complications and mortality compared with historical controls for 1 or 2 level procedures. We found clinical resolution and absence of complications requiring return to the operating room in 75% of patients when complete extirpation of the involved vertebrae is achieved. Our findings suggest multilevel anterior corpectomies with posterior stabilization may be a reasonable surgical option when approaching patients with complicated spondylodiscitis. © 2018 Elsevier Inc. All rights reserved.

Keywords: Corpectomy; Outcomes; Pyogenic vertebral osteomyelitis; Spinal infections.

Introduction

Pyogenic vertebral osteomyelitis (PVO) is a potentially life-threatening condition and is associated with significant morbidity and mortality [1]. PVO is a common problem, with large-scale epidemiologic studies reporting an annual incidence of 2.2 per 100,000 people [2,3]. Early stages of the disease are often responsive to medical management. The patients with PVO who develop mechanical spinal instability, epidural abscess, neurologic deficits, or infections that are refractory to antibiotic therapy are considered appropriate candidates for surgical intervention [4–8].

Surgery may be undertaken for identification of pathogens and antimicrobial susceptibilities but more commonly aims to achieve debridement of infected and necrotic tissues, decompression of surrounding neuronal structures, and stabilization of deformed and unstable vertebral segments. It is generally agreed that anterior debridement is preferred when surgical intervention is indicated [8–11], because vertebral osteomyelitis predominantly involves the vertebral body, with involvement of the posterior elements in only 5% of cases [12,13].

More extensive cases may necessitate multilevel corpectomies to achieve the primary goal of adequate debridement. To date, no previous research has focused on the results of surgery for PVO requiring two or more contiguous corpectomies. These extensive procedures present a unique set of challenges in terms of exposure, adequacy of debridement, surgical duration, and mechanical stability.

The purpose of this report is to describe our experience in the operative management of PVO in 56 consecutive patients who underwent multilevel corpectomies (≥2) via a combined approach.

Materials and methods

Study population

Institutional review board approval was granted for a single institution retrospective cohort review between January 2002 and December 2015. All the patients had been treated at an academic tertiary referral center by one of two

fellowship-trained orthopedic spine surgeons. Hospital billing data were queried using vertebral corpectomy procedure codes 63081, 63085, 63087, and 63090. Patient records were subsequently cross-referenced with International Classification of Diseases osteomyelitis codes 730.0, 730.1, and M46.2, and paravertebral abscess code 324.1. The resulting cohort consisted of 131 patients. The inclusion criteria for the study were patients within the cohort who had adequate medical records for review, a minimum patient age of 18 years, active vertebral osteomyelitis as an indication for surgical intervention, a minimum of 1-year radiographic follow-up, and surgical intervention that included at least two complete vertebral corpectomies (Fig. 1). Fifty patients were excluded because they received partial or single level corpectomy, and 25 patients were excluded because they were lost to follow-up and had inadequate records. Subsequently, 56 patients met the inclusion criteria and were reviewed for this retrospective analysis.

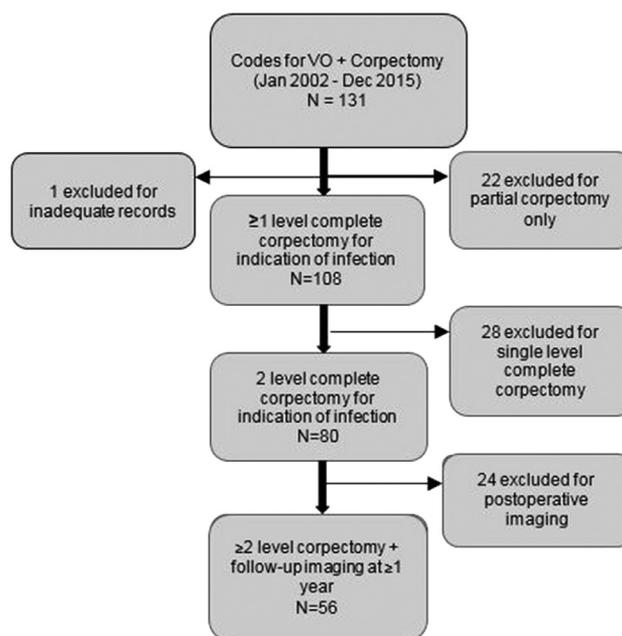


Fig. 1. Flowchart of inclusion criteria applied to study cohort.

Data collection

Data were collected in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology [14] (STROBE) guidelines and included demographic information, comorbidities, social and surgical histories, preoperative antibiotic treatment, operative and perioperative data (including length of stay and in-hospital postoperative complications), readmissions and reoperations for vertebral osteomyelitis, and/or procedure-related complications, and postoperative imaging.

Outcomes of interest were readmission and reoperation rates related to treatment of PVO, 30-day and 1-year mortality rates, radiographic outcomes, perioperative complications, infection control, and length of stay. Mortality was determined by medical chart review and query of the Social Security Death Master File (National Technical Information Service, 2014). Patients who did not survive to discharge during their index admission (n=9) were excluded from length of radiographic follow-up and readmission rate analyses.

Preoperative diagnosis was made using history, elevated erythrocyte sedimentation rate, C-reactive protein, and white blood cell count. Diagnostic imaging included anteroposterior and lateral radiographs, magnetic resonance images, and computed tomographic scans. Preoperative medical management consisted of long-term IV antibiotics and bracing. Patients were referred from numerous community hospitals that have no shared treatment protocols. Non-operative medical management, including IV antibiotics, had failed for all patients, and all patients presented with intractable pain and progressive vertebral body destruction. Additional surgical indications included epidural, psoas, or retroperitoneal abscess, severe progressive kyphotic deformity, and neurologic impairment.

The surgical procedure consisted of anterior debridement with stabilization using a titanium cage in all but two patients who were treated with autogenous tricortical iliac bone graft—one a two-level cervical corpectomy and the other a T12–L1 two-level corpectomy (Fig. 4). All obviously infected or necrotic bone was removed until healthy bleeding cancellous bone was seen or until an uninfected disc had been resected. Decompression of the spinal canal was performed when clinically indicated. Once the debridement was complete the resulting defect was spanned with a titanium implant. Both static and expandable implants were used at the surgeon's discretion. Cages were filled with morselized autograft and crushed cancellous allograft bone. Recombinant human BMP was used in three patients—none required readmission and all were still living at 1 year. All anterior surgeries were followed by immediate or delayed posterior stabilization in staged fashion. No patient was treated with anterior stand-alone instrumentation.

Statistical analysis

Data were collected and entered into an electronic spreadsheet (Microsoft Excel; Microsoft Corporation, Redmond,

WA, USA). Analysis of data was performed using statistical software (JMP Pro 13; SAS Institute Inc., Cary, NC, USA). A Fisher's exact test was used for direct comparison of binary variable proportions. Logistical regression was used to compare categorical and continuous variables. Nonparametric continuous variables were compared using either Median or Wilcoxon Rank Sum Tests, and normally distributed continuous variables were compared using the Student *t* test. Stepwise regression was performed to identify variables associated with primary outcomes.

Results

Study population

Fifty-six patients were included for review: 62.5% men; mean age, 56.8 ± 11.7 years; mean body mass index (BMI), 27 ± 7.6 m²/kg. Full demographic data are presented in Table 1. Additional characteristics of the study group included 45% with diabetes mellitus (DM), 25% with documented active or former IV drug abuse (IVDA), 64% were current or former smokers, and 32% with compromised immunity caused by disease or prescribed medication. More than half of the patients (59%) had undergone at least one previous spine surgery in the region of spondylodiscitis.

Surgical data

The mean number of complete vertebrectomies was 2.25 ± 0.64 SD, the mean number of anteriorly fused vertebrae was 4.14 ± 1.02 SD, and the mean number of posterior fusions was 5.5 ± 3.25 SD. Full surgical data are presented in Table 2. Half of the patients were managed with a staged operation.

We found no statistical significance between single and staged surgeries when comparing EBL (p=.15), intraoperative blood transfusion requirements (p=.38), or reoperation rate (p=.33). Mean estimated blood loss (EBL) for staged and nonstaged procedures was 2,669 mL and 1,944 mL, respectively. Mean number intraoperatively transfused

Table 1
Patient demographics

Demographic	Data
Total patients, n (%)	56 (100)
Male sex, n (%)	35 (62.5)
Age (y), mean (range)	56.80 (32.7–79.7)
BMI (kg/m ²), mean (range)	26.9 (16.2–54.5)
Diabetes mellitus, n (%)	25 (44.6)
IVDA*, n (%)	14 (25)
Smoker†, n (%)	36 (64.3)
Immunosuppressed, n (%)	18 (32.14)
Corpectomy levels	
Cervical, n (%)	6 (10.7)
Thoracic, n (%)	24 (42.9)
Lumbar, n (%)	26 (46.4)

* IVDA indicates intravenous drug abuser.

† Includes both active and former.

Table 2
Surgical data

Variable	Total	Staged	Nonstaged	p Value
Patients	28	28	28	–
Previous spinal procedure, n (%)	33 (58.9)	16	17	1
Reoperation	12	8	4	.33
Complete vertebrectomies, mean (\pm SD, range)	2.25 (\pm 0.64, 2–5)	–	–	–
EBL (mL), median	1,650	2,669	1,944	.15
Intraoperative PRBC, median units	5	6.18 (mean)	5.08 (mean)	.38
Vertebrae fused anteriorly, mean (\pm SD)	4.14 (\pm 1.02)	–	–	–
Vertebrae fused posteriorly, mean (\pm SD)	5.5 (\pm 3.25)	–	–	–

EBL, estimated blood loss; PRBC, packed red blood cells transfused during surgery.

PRBC units for staged and nonstaged procedures was 6.18 and 5.08 units, respectively. Median length of stay was 13 days (range 4–63 days) for patients who survived to discharge after the index procedure (n=47). For those surviving beyond 1 year (n=45), median radiographic follow-up was 2.75 years (range 1–9.5 years). Patient outcomes may be viewed in [Table 3](#).

Radiographic data demonstrated 14 of the 43 patients (32.6%) that had anterior column support with a cage consequently experienced some degree of subsidence or cage migration. Of these patients, none required revision of the anterior construct. Seven of these required revision surgeries. These patients are more thoroughly discussed in the reoperation section of this manuscript.

Mortality

Thirty-day and 1-year mortality rates were 7.14% and 19.6%, respectively. Of the 11 patients who died within a year of the index surgery, 9 expired within their initial hospital visit (2 in operating room and 7 post-operatively) and two expired after discharge (At 300 and 236 days, respectively). The cause of both intraoperative deaths was specifically iliac vein injury with massive uncontrollable hemorrhage. Most common cause of postoperative death was infection related (n=6; 55%). A detailed list of individual causes and postoperative day of expiration is presented in [Table 4](#).

Table 3
Patient outcomes

Outcome	Data
PVO-related readmission rate*, n (%)	22 (46.8)
Median time to readmission, days (range)	222.5 (13–2,936)
PVO-related reoperation*, n (%)	12 (25.5)
Median time to reoperation, days (range)	396 (53–2,938)
30-day mortality, n (%)	4 (7.14)
1-year mortality rate, n (%)	11 (19.6)
Perioperative complications, n (%)	31 (55.4)
Median length of stay, days (range)	13 (4–63)
Median length of radiographic follow-up, years (range)	2.75 (1.03–11.6)
Radiographic evidence of subsidence or cage migration	14 (32.6)

* PVO indicates pyogenic vertebral osteomyelitis.

Increased patient age was significantly associated with 1-year mortality (p=.028, OR 1.11, CI 1.01–1.20). Mean patient age at the time of index operation in those surviving beyond 1 year and those surviving less than 1 year after the index procedure was 54.5 \pm 11.4 years and 66.0 \pm 8.1 years (p=.001), respectively. Stepwise regression modeling revealed age as a significant predictor of mortality at 1 year (p=.002). IVDA was initially negatively associated with 1-year mortality in bivariate analysis (p=.05). However, no significant association was observed after accounting for patient age, as patients with documented IVDA were younger than those without documented IVDA.

Readmission

After excluding in-hospital mortalities, readmission rate for events related to management of PVO was 47% (22 of 47 patients), with a median time to readmission of 222.5 days (range 13–2,936 days). Twelve of these patients subsequently underwent reoperation. Infectious complications accounted for 8 of 22 (36%) readmissions, with half of these patients returning to the OR for subsequent incision and drainage with removal of instrumentation. The cause and timing of readmissions are presented by patient in [Table 5](#).

Total EBL was significantly associated with readmission (p=.03), with EBL >1,500 mL resulting in a nearly sixfold increased odds of readmission (p=.01, OR 6.39, CI

Table 4
All causes of death

Cause of Death	Postoperative day
<i>Infectious</i>	
Pneumonia, sepsis	10
Septic shock, respiratory failure	12
Recurrent paraspinal abscess, endocarditis	19
Sepsis	26
Spinal osteomyelitis, infected aortic endograft	37
Septic shock, renal failure	48
<i>Medical</i>	
Metastatic cancer	66
Myocardial infarction	236
Other comorbidities	300
Intraoperative death (hemorrhage)	0
Intraoperative death (hemorrhage)	0

Table 5
Patient readmissions

Reason for readmission	Age (y)/sex	Corpectomy levels	Time from index procedure (d)
<i>Medical</i>	–	–	–
Clogged PICC line	38/M	T8–T9	33
Altered mental status	38/F	T7–T8	109
Seizure	54/F	T9–T10	22
Back and abdominal pain	69/F	L3–L5	25
Hypoglycemia	55/F	T12–L1	221
<i>Infectious</i>			
Transferred back for IV antibiotics and slow removal of chest tube drain	52/F	T5–T7	13
Possible paravertebral abscess	53/M	T8–T9	142
Postoperative wound infection at site of lumbar surgery (index corpectomy was mid-thoracic)	42/F	T7–T8	38
Progression of infection	68/F	L1–L2	224
<i>Miscellaneous</i>			
Lower extremity weakness	58/M	L2–L3	1,716

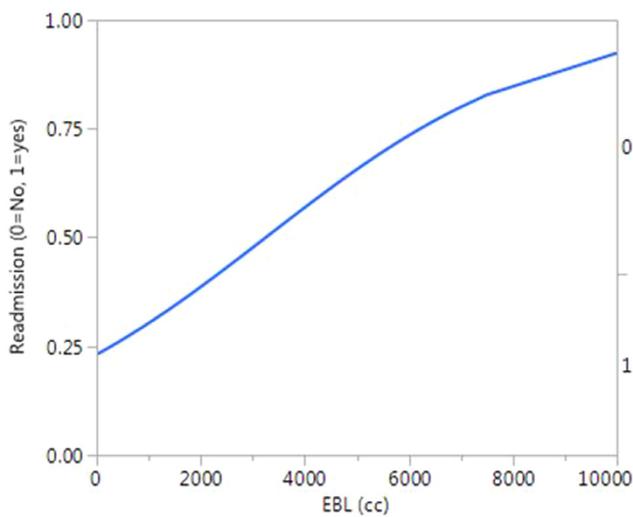


Fig. 2. Logistic fit of readmission by EBL.

1.24–32.89). All patients (n=4) with an EBL >4,000 mL were readmitted. Stepwise regression modeling revealed EBL as a significant predictor for readmission when controlling for age (p=.01). The logistic fit graph of readmission probability versus EBL alone is shown in Fig. 2. No significant difference in the rate of readmission between patients undergoing staged and nonstaged procedures was observed.

Reoperation

Rate of reoperation was 22.2% (n=12), occurring at a median time of 396 days after the index surgery. All patients requiring reoperation subsequently underwent a posterior procedure, and none of these required revision of anterior instrumentation. Reoperations are presented by patient in Table 6. Of these 12 patients, three underwent incision and drainage (I&D) with removal of posterior

Table 6
Patient reoperations

Procedure	Age (y)/sex	Corpectomy levels	Time from index procedure (d)
<i>Instrumentation complications</i>			
Removal of segmental spinal instrumentation	42/M	L3–L5	133
Revision of posterior thoracic spinal fusion with reinsertion of segmental fixation and allograft bone	62/M	T4–T7	306
Removal of posterior instrumentation	46/F	L3–L4	1,385
Removal of instrumentation	32/F	L2–L3	1,204
<i>Infectious</i>			
I&D with removal of instrumentation	43/F	L4–L5	486
I&D with removal of posterior instrumentation	35/M	L3–L4	245
I&D and removal of instrumentation	57/M	T9–T10	291
I&D, removal, reinsertion, and extension of instrumentation	67/M	L1–L2	53
<i>Miscellaneous</i>			
ACDF with PCF; T1 spinous process biopsy performed 8 months later for chronic osteomyelitis	50/M	C4–C5	105
Instrumented fusion and vertebroplasty	52/F	L4–L5	656
PCDF	51/M	C6–C7	2,938
PLIF with segmental instrumentation	69/M	L2–L3	570

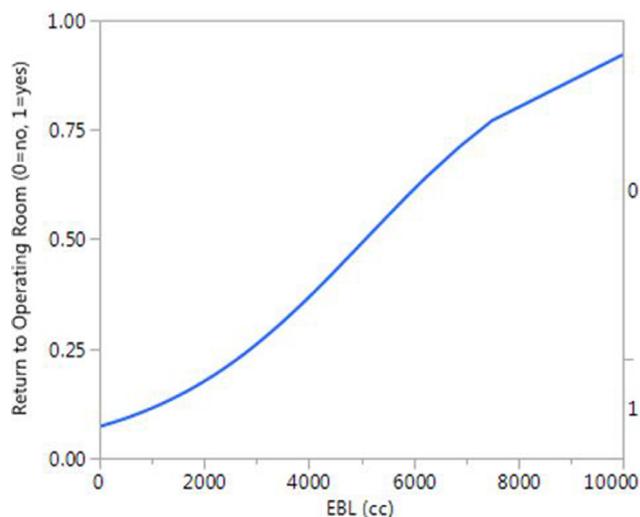


Fig. 3. Logistic fit of reoperation by EBL.

instrumentation secondary to infection recurrence and one underwent I&D and reinsertion of instrumentation secondary to infection recurrence and posterior instrumentation failure. Four patients required removal of painful prominent instrumentation after resolution of infection. Each of these patients underwent work up with laboratory studies and advanced imaging to rule out recurrent infection or pseudoarthrosis before undergoing instrumentation removal. Additionally, 3 of the 12 patients underwent correction of proximal junctional kyphosis or adjacent level disease and one required extension of the fusion as a result of a cervical fracture dislocation and central cord syndrome.

Total EBL was significantly associated with need for reoperation ($p=.05$), with EBL $>1,500$ mL resulting in a fourfold increased risk of reoperation ($p=.01$, OR 4.22, CI 1.29–13.8). Stepwise regression modeling revealed EBL as a significant predictor for readmission ($p=.004$). The logistic fit graph of reoperation probability versus EBL alone is shown in Fig. 3. No significant difference in rate of reoperation between patients undergoing staged and nonstaged procedures was observed.

Discussion

PVO remains a challenging disease despite widespread availability of advanced diagnostic techniques and modern medical management with antibiotics. Multiple patient factors have been associated with PVO, listed as follows: advanced age, DM, immune compromise, IVDA, those who have undergone previous spinal surgery, and those who have established infectious foci. In our series, 37.5% of the patients were immunocompromised, and the mean patient age at the time of operation was 56.8 years, which is slightly younger than in previous series (59–67.9 years) [2,10,15,16]. Additionally, our cohort included more patients with DM (45% vs. 11–35%) and active or former IVDA (25% vs. 17–32%) compared with previous studies

[3,10,15–18]. In an 11-year retrospective review, Weissman et al. [19] found that 23 (20%) of the patients had undergone previous spinal surgery before the infectious episode and that 13 (11%) had received a previous prosthetic implant at the infection site. More than half (59%) of the patients in the study cohort had undergone previous spine surgery at the same level of the diagnosed spondylodiscitis.

Surgery is an option for patients with uncontrolled sepsis, neurologic impairment, instability, significant deformity, intractable pain, or failure of appropriate antibiotic therapy. Several large clinical series have reported surgical intervention in 40% to 60% of patients; however, the surgical technique remains controversial [10,20]. The guiding principles in the surgical treatment of osteomyelitis are radical debridement of necrotic and infected tissue and restoration of alignment and stability. Radical debridement can result in large segmental defects. Restoration of anterior column stability is necessary [21]. We used titanium mesh or expandable cages in conjunction with morselized autograft and cancellous allograft in all our patients except two for whom we used autogenous tricortical iliac graft to restore the anterior column. Rigid posterior instrumentation was applied to secure our anterior construct with either an open or percutaneous technique. This study included both single and staged surgeries.

Titanium cages in combination with posterior instrumentation achieve stability similar to that of the intact spine [22]. Thus, they are an excellent means of bridging large defects and supporting anterior load until the bony fusion of the cancellous bone graft is completed. Patients can be mobilized within the first few postoperative days, which is of considerable importance in an older patient population with multiple medical comorbidities (Fig. 4).



Fig. 4. Pre- and postoperative CT imaging of a 71-year old Caucasian man who developed pathologic kyphosis caused by chronic osteomyelitis at L1–L2. The patient underwent posterior reconstruction before anterior vertebral corpectomy at L1–L2 with T12–L3 anterior spinal fusion and anterior column support with a cage.

In this series, using the technique described, revision was required in 12 patients, mostly for removal of posterior instrumentation secondary to recurrence of infection or late pain. No revisions, however, were performed for either mechanical or infectious failure of the anterior construct. We highlight this as an important consideration when approaching multilevel corpectomies as a surgical treatment for complicated spondylodiscitis, as revision surgery for anterior construct failure is a potentially highly morbid procedure with high rate of complications.

In the retrospective review by Weissman et al. [19], surgical intervention was required in 81% (n=95) of the vertebral osteomyelitis cases, with 54% (n=63) receiving implantation of prosthetic material. In that study, the readmission rate for the management of vertebral osteomyelitis was 26% (n=30), with 21% (n=24) requiring subsequent repeat operation. The authors did not discuss the type of procedure performed. Theologis et al. [23] studied multilevel corpectomies in 19 patients with subaxial cervical osteomyelitis with an average follow-up of 16 months and found that 26% (n=5) of the 19 patients required secondary revision surgery, two of which were secondary to anterior cage/graft dislodgment. Our readmission and reoperation rates were 43% and 22%, respectively. A total of 14 of 43 patients (32.6%) experienced some degree of subsidence or anterior cage migration. Seven required removal of posterior instrumentation with four of these requiring irrigation and debridement. It should be noted that one of our inclusion criteria was that patients had failed nonoperative treatment before surgical intervention. Because of this, patients presented with more complicated and advanced spondylodiscitis, thus making surgical intervention the only remaining option. Likewise, the mortality rate was substantial, with seven patients expiring during the acute hospitalization. Our population had particularly high rates of serious comorbidities in conjunction with their extensive infections, including 45% with diabetes mellitus (DM), 25% with documented active or former IV drug abuse (IVDA), 64% were current or former smokers, and 32% with compromised immunity caused by disease or prescribed medication. The authors believe that the overall mortality rate is a reflection of the debilitated nature of the patients in conjunction with their late presentation with extensive disease.

Single versus two-stage procedures

The decision to perform anterior-posterior spinal surgeries in a single operation or through a staged approach is complex. When feasible, single-stage surgery can achieve the surgical goals with less operative time, potentially fewer complications, earlier mobilization, and shorter hospital stays. Two-stage surgery may be necessary to permit resuscitation between surgical procedures. In addition, there may be concern that septic emboli from the anterior debridement could contaminate the posterior instrumentation and staging the procedures may reduce the incidence

of posterior wound problems and recurrent infection. In our series, there was no statistical significance between single and staged surgeries when comparing the rate of complications, EBL, intraoperative blood transfusion requirements, or reoperation rate ($p=.32$). As long as the patient remains hemodynamically stable with no evidence of coagulopathy, it appears that both anterior and posterior procedures may be safely accomplished in a single operative setting.

Study limitations

This is the largest study to date regarding the operative management of this unique population; however, some limitations exist. The high rate of substance abuse and medical comorbidities make this a challenging population to study. We report 30% (24 of 80 patients) of 80 patients meeting qualifying criteria were deemed ineligible due to inadequate follow-up records. Additionally, there may have been patients clinically judged not to be candidates for operative management during the time period of this retrospective review. The reoperation rate reported may be subject to some degree of selection bias. Factors such as patient reported pain, clinical examinations of instrumentation prominence, and radiographic evaluation of instrumentation loosening were subject to surgeon discretion when making the decision for reoperation. The absence of validated pre- and postoperative pain, function, and quality of life questionnaires prevent us from more detailed evaluations of functional outcomes after our surgical treatment for PVO. Additionally, pre- and postoperative management regarding antibiotic type and duration, along with definitive biopsy verifying disease eradication, was not available due to the retrospective nature of this review and limitations of institutional protocol concerning postoperative management of these patients. Nonetheless, this is the largest series to date treated with multilevel corpectomies in a combined anterior-posterior approach.

Conclusions

Multilevel vertebral corpectomy for the treatment of PVO is a challenging procedure with many inherent risks. Radical debridement and restoration of stability are prerequisites for infection control and bony fusion. In our study, if patients had absence of progression of vertebral destruction, no progression of deformity, absence of signs of sepsis or persistent infection (radiographic evidence of hardware loosening, elevated laboratory values such as ESR and CRP), and no related complications requiring return to the operating room, we deemed this control of disease and effective eradication. We report disease control with this approach in 75% of patients. No patients in our cohort required revision of their anterior construct. Despite a substantial complication rate, these findings suggest multilevel anterior corpectomies with posterior stabilization may be a

reasonable surgical option when approaching patients with complicated spondylodiscitis.

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