Therapeutic Outcomes of Hematogenous Vertebral Osteomyelitis With Instrumented Surgery

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Background. Patients with hematogenous vertebral osteomyelitis (HVO) occasionally require instrumentation for spinal stabilization. However, placing instrumentation in the setting of spinal infection raises concerns about recurrent infection due to bacteria adhering to the foreign material. In this study, we evaluated the therapeutic outcomes of patients with HVO who underwent instrumented surgery.

Methods. We conducted a retrospective chart review of adult patients with microbiologically diagnosed HVO who underwent surgical intervention in 5 tertiary care hospitals over an 8-year period.

Results. A total of 153 patients with HVO underwent surgical management for their infections. Of these 153 patients, 94 (61.4%) underwent surgical debridement alone (noninstrumented surgery) and 59 (38.6%) underwent surgical debridement and instrumentation (instrumented surgery). The median durations of antibiotic therapy were 66 and 80 days for the noninstrumentation and instrumentation groups, respectively ($P = .22$). Clinical outcomes were similar between the groups, including rates of infection-related death (2.1% vs 0%; $P = .52$), primary failure (1.1% vs 5.1%; $P = .30$), and recurrence (4.8% vs 6.8%; $P = .72$). Among the instrumentation group, there was a significant decreasing trend for recurrence according to total duration of antibiotic therapy: 22.2% (4–6 weeks), 9.1% (6–8 weeks), and 2.6% (≥8 weeks; $P = .04$). Duration of pre-instrumentation antibiotic therapy and single-stage operation (vs 2-stage operation) were not risk factors for recurrence.

Conclusions. Spinal instrumentation in patients with HVO may be safe with pathogen-directed prolonged antibiotic therapy and should not be abandoned or delayed solely because of the risk of recurrence.

Keywords. vertebral osteomyelitis; spondylitis; antibiotic; treatment; outcome.

The occurrence of hematogenous vertebral osteomyelitis (HVO) has increased in recent years, likely due to longer life expectancies, higher prevalence of chronic diseases, and improved diagnostic techniques [1–3]. HVO is associated with significant morbidity including decreased functional status and risk of recurrence [4, 5]. Although HVO is usually treated conservatively with appropriate antibiotic therapy, under certain situations, such as abscess formation, unresponsiveness to antibiotics, intolerable pain, and presence of neurological deficits, surgery is indicated [6–8]. Surgical intervention involves debridement and decompression, sometimes accompanied by instrumentation for spinal stability if stability is compromised by the infection or through the debridement process [9].
Surgical debridement with spinal instrumentation can relieve pain, improve sagittal balance and neurological function, and result in early ambulation [9]. Despite these benefits, placing instrumentation in the setting of spinal infection raises concern for the continued presence of bacteria that adhere to the foreign material, resulting in infection recurrence. Thus, several authors have advised that antibiotic administration should last at least 6–8 weeks in patients who undergo spinal instrumentation [10–13]. Because of the perceived risk of residual bacteria, some surgeons prefer a 2-stage operation (radical debridement with antibiotic therapy and delayed instrumentation) vs debridement and instrumentation in a single-stage operation [9]. Many issues, such as the safety of instrumentation in a setting of spinal infection, duration of antibiotic therapy, and a single-staged vs 2-staged operation, remain controversial. Thus, we performed a retrospective cohort study to evaluate the therapeutic outcomes in patients with HVO requiring instrumented surgery.

METHODS

Study Design and Setting
This observational cohort study was undertaken at 5 tertiary-care hospitals in the Republic of Korea (3 in Seoul, 1 in Jinju, and 1 in Busan). The study included all adult patients diagnosed with HVO who underwent surgical management from January 2005 through December 2012. We identified all discharge records that included the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes for osteomyelitis of the vertebral disk (M46.2), pyogenic infection of intervertebral disk (M46.3), unspecified discitis (M46.4), other infective spondylosis (M46.5), other specified inflammatory spondylitis (M46.6), unspecified spondylitis (M46.8), and epidural abscess (G06). Discharge records containing these ICD-10-CM codes were reviewed to determine whether they met the study criteria defined below. This study was reported using the format recommended by Strengthening the Reporting of Observational Studies in Epidemiology guidelines [14].

Inclusion and Exclusion Criteria
Adult patients (aged ≥16 years) with HVO who underwent surgical management for their infections were included. HVO was defined as both radiographic evidence of vertebral osteomyelitis and microbiological demonstration of bacterial pathogens either from the site of infection (eg, abscess, intervertebral disc, vertebral bone) or the blood. To clarify the association between antibiotic treatment and clinical outcomes, we included only microbiologically proven cases. Cases were excluded if there was a nonhematogenous source of vertebral infection, including penetrating trauma, previously placed hardware, laminectomy within 1 year prior to the vertebral osteomyelitis diagnosis, and the presence of a stage 3–4 decubitus ulcer at the time of diagnosis [15–17]. Other reasons for exclusion were incomplete medical records, ≤4 weeks of antibiotics, and transfer to another hospital before completing antibiotic therapy.

Data Collection
Medical records were reviewed retrospectively for demographic information, underlying illness/conditions, presumed source of infection, other concurrent metastatic infections, clinical presentation, laboratory and radiological data, medical and surgical treatments, and clinical outcomes. During the study period, the antibiotic regimen and duration of therapy were usually determined by infectious diseases specialists, based on culture results. Surgical therapies were performed at the discretion of the treating physician.

Definitions
Instrumentation surgery was defined as surgery that involved the use of implanted devices, including titanium cages, plates, screws, rods, and hooks. Bone grafting without instrumentation was not categorized as instrumentation surgery.

Clinical outcomes were evaluated using the following measures: infection-related death, primary failure, recurrence, and sequelae. Infection-related death was defined as in-hospital death related to the infection or to its treatment. Primary failure was defined as patients with a need for a new surgical debridement after surgical intervention before the end of antibiotic treatment because of signs of uncontrolled infection. Recurrence was defined as patients with recurrent symptoms and signs after the completion of antibiotics and who received a second course of parenteral antibiotic treatment. Patients were considered to have microbiological recurrence if a needle or open biopsy or blood cultures revealed the same organism that caused the initial infection. Patients were considered to have clinical recurrence if repeated diagnostic biopsy and blood cultures did not reveal the causative organism(s) but both clinical and laboratory improvement were evident after reintroduction of antibiotic therapy [17]. Sequelae were defined as persisting signs and symptoms related to osteomyelitis for at least 12 months after completing treatment, including paresis necessitating wheelchair use, bladder/bowel incontinence, and/or unresolved pain that required analgesic therapy [15–17].

Statistical Analysis
All statistical analyses were performed using the SPSS software (version 18.0 for Windows; SPSS, Inc., Chicago, Illinois). Categorical variables were compared using χ² or Fisher exact tests. For ordinal data, we used a linear-by-linear association test. Continuous variables were compared using Student t tests or Mann–Whitney U tests. Event-free survival and recurrence-free survival were determined in all patients and those who completed antibiotic treatment, respectively, using the Kaplan–Meier.
method. Event-free survival was defined as the time period from the date of surgical intervention to infection-related death, primary failure, or recurrence. Recurrence-free survival was defined as the time period from the date of completing antibiotic treatment to recurrence. We compared survival curves of the 2 groups using the log-rank test. All statistical tests were 2 tailed, and a P value ≤ .05 was considered to indicate statistical significance.

RESULTS

A total of 167 patients with microbiologically diagnosed HVO who underwent surgical debridement were identified during the study period. Of the 167 cases, 14 were excluded for the following reasons: transferred to other hospitals before completing antibiotic therapy (n = 7), <4 weeks of antibiotic therapy (n = 4), or incomplete medical records (n = 3). Thus, 153 patients met the inclusion criteria and were included in our study.

Patient Characteristics

The median age of the cohort was 66 years, and 78 (51.0%) patients were males. Forty-eight (31.4%) patients had diabetes mellitus, and 10 (6.5%) patients had underlying malignancies. Surgical debridement was performed in all 153 patients, and the median time from diagnosis to initial debridement surgery was 6 days (interquartile range [IQR], 2–15). Of the 153 patients, 94 (61.4%) underwent surgical debridement alone (non-instrumentation group) and 59 (38.6%) underwent surgical debridement as well as spinal instrumentation (instrumentation group; Table 1). Among the 59 patients who underwent spinal
instrumentation, 24 (40.7%) underwent single-stage operations and 35 (59.3%) underwent 2-stage operations, with a median interval of 10 days (IQR, 6–14). White blood cell counts were lower in the instrumentation group than in the noninstrumentation group (median 10.3 vs 12.6 × 10⁹/L; \( P = .02 \)). Thoracic spine involvement was more common in the instrumentation group than in the noninstrumentation group (35.6% vs 20.2%; \( P = .04 \)). There was no difference in other baseline characteristics between the groups (Table 1).

**Microbiological Diagnosis**

The most frequently isolated organisms were *Staphylococcus aureus* (52.9% [81/153]), and of these, 38.3% (31/81) were methicillin resistant. Thirty-seven (24.2%) cases were caused by aerobic gram-negative bacteria, and 17 (11.1%) cases were caused by *Streptococcus* species. There was a trend toward a higher frequency of methicillin-susceptible *S. aureus* (MSSA) in the noninstrumented surgery group than in the instrumented surgery group (36/94 [38.3%] vs 14/59 [23.7%]; \( P = .06 \)). There was no difference in the proportions of other causative organisms between the groups (Supplementary Table 1).

**Antibiotic Treatment**

All patients received intravenous antibiotics as a component of their initial treatment. The median duration of intravenous antibiotic therapy was 45 days (IQR, 33–62) for the noninstrumentation group and 53 days (IQR, 36–76) for the instrumentation group (\( P = .19 \)). Oral antibiotics were prescribed after intravenous antibiotic therapy was completed in 53.2% (50/94) of the noninstrumentation group and in 62.7% (37/59) of the instrumentation group (\( P = .25 \)). The median duration of total antibiotic therapy did not differ between the groups (66 [IQR, 45–112] vs 80 [IQR, 52–126] days; \( P = .22 \)). The details of antibiotic treatments are summarized in Supplementary Table 2.

**Therapeutic Outcomes**

The outcomes of patients who underwent noninstrumented surgery and with instrumented surgery are shown in Table 1. Median follow-up duration after surgical intervention was 39 months for the noninstrumentation group and 45 months for the instrumentation group (\( P = .07 \)). Ten (10.6%) patients who underwent noninstrumented surgery and no patients who underwent instrumented surgery died during the hospital stay. Infection-related death rates were 2.1% (2/94) for noninstrumented surgery and 0% (0/59) for instrumented surgery (\( P = .52 \)). Primary failure rates also did not differ between the groups (1.1% [1/94] vs 5.1% [3/59]; \( P = .30 \)).

A total of 143 patients completed the initial course of antibiotic therapy and were evaluable for recurrence. Four (4.8%) of 84 patients who underwent noninstrumented surgery and 4 (6.8%) of 59 patients who underwent instrumented surgery experienced recurrence (\( P = .72 \)) (Table 1). Of the 8 patients with recurrence, 5 experienced microbiological recurrence and 3 experienced clinical recurrence. Median time to recurrence after completing antibiotic therapy was 35 days (range, 14–88). Details of the 8 patients with recurrence are shown in Supplementary Table 3. Overall, event-free survival (time to infection-related death, primary failure, or recurrence) did not differ between the noninstrumentation and instrumentation groups (log-rank test, \( P = .41 \); Figure 1A). A linear-by-linear association test revealed a significant decreasing trend of recurrence according to duration of all antibiotic therapy: 22.2% (4–6 weeks), 6.7% (6–8 weeks), and 2.1% (\( \geq 8 \) weeks; \( P = .001 \); Figure 2A). This association was also seen in the noninstrumentation group (22.2%, 5.3%, and 1.8%, respectively; \( P = .02 \)) and the instrumentation group (22.2%, 9.1%, and 2.6%, respectively; \( P = .04 \); Figure 2B). Baseline characteristics of patients according to duration of antibiotic therapy are shown in Supplementary Table 4.

Univariate analysis indicated that <6 weeks of antibiotic therapy was the only risk factor for recurrence in patients who underwent surgical management (\( P = .009 \)); spinal instrumentation was not associated with recurrence (\( P = .72 \); Table 2). Kaplan–Meier

![Figure 1.](cid:2015:60 (1 May) • 1333)
analysis showed that recurrence was more common in patients treated for <6 weeks with antibiotics than in those treated for ≥6 weeks with antibiotics (log-rank test, P < .001; Figure 1B).

Among those in the instrumentation group, recurrence rates differed according to the duration of post-instrumentation antibiotics: 27.3% (<4 weeks), 0% (4–6 weeks), and 2.8% (≥6 weeks) (P = .02). However, recurrence rates did not differ according to the duration of pre-instrumentation antibiotics: 5.6% (<4 weeks), 25.0% (4–6 weeks), and 5.3% (≥6 weeks) (P = .93; Figure 2C). Neither mode of surgical approach (anterior, posterior, or combined approach) nor single-stage (vs 2-stage) operation was associated with recurrence (Table 2).

Among 126 patients evaluable for sequelae, sequelae rates did not differ in the noninstrumentation and instrumentation groups (28.2% vs 34.5%; P = .44; Table 1). Univariate analysis indicated that time to diagnosis of ≥3 weeks (P = .02), neurological deficit (P = .006), and cervical/thoracic spine involvement (P = .002) were significant risk factors for sequelae. Spinal instrumentation

Figure 2. A, Recurrence rates of hematogenous vertebral osteomyelitis in patients who underwent surgery according to the duration of antibiotic therapy and intravenous antibiotic therapy. B, Associations between duration of all antibiotic therapy and recurrence rates in the noninstrumentation and the instrumentation groups. C, Associations between duration of pre- and post-instrumentation antibiotic therapy and recurrence rates among patients who underwent instrumented surgery. All P values were calculated using a linear-by-linear association test.
was not associated with sequelae ($P = .44$; Table 3). Multivariate analysis indicated that independent risk factors for sequelae were time to diagnosis of $\geq 3$ weeks (adjusted odds ratio [aOR], 2.72; 95% confidence interval [CI], 1.18–6.25; $P = .02$), neurological deficit (aOR, 2.68; 95% CI, 1.05–6.86; $P = .04$), and cervical/thoracic spine involvement (aOR, 2.84; 95% CI, 1.21–6.64; $P = .02$).

**DISCUSSION**

This study is one of the largest to evaluate the therapeutic outcomes in patients with HVO who underwent surgical interventions. Among patients with HVO who underwent surgical debridement, placement of spinal instrumentation did not adversely affect the clinical outcome. Our data suggest that pathogen-directed antibiotic treatment of $\geq 6$ weeks may benefit patients with vertebral osteomyelitis who undergo spinal instrumentation.

A recent systematic review of 30 studies published between 1998 and 2006 reported only 1.7% (12/689) of infection recurrence among patients who underwent instrumented surgery [18]. Low rates of infection recurrence were also reported in 2 recent studies (4.3% in one [18] and 3.1% in the other [19]).
these findings, placing instrumentation in the setting of spinal infection still raises concern for infection recurrence, and drawing conclusions from those studies is difficult for several reasons. Many of these studies were limited by a lack of strict case definitions, small case numbers, and vague descriptions of antimicrobial therapy [18, 19]. Also, these studies reported outcomes of instrumented patients only; comparison groups of patients who underwent debridement only were not included [18, 19]. Our study had a large cohort of patients, with standardized cases, outcome definitions, and a comparison group. Additionally, to exclude the noninfectious diagnoses and to clarify the association between duration of antibiotic treatment and recurrence, we included only microbiologically proven cases of HVO. In our study, infectious diseases specialists usually prescribed pathogen-directed antibiotic treatment based on results of culture by either intravenous or oral routes.

Table 3. Univariate Analysis of Risk Factors for Sequelae Among Patients With Hematogenous Vertebral Osteomyelitis Who Underwent Surgical Intervention

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Sequelae (n = 87)</th>
<th>Sequelae (n = 39)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among all patients who underwent surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, years, median (IQR)</td>
<td>65 (56–71)</td>
<td>67 (63–74)</td>
<td>.15</td>
</tr>
<tr>
<td>Male sex</td>
<td>45 (51.7)</td>
<td>18 (46.2)</td>
<td>.56</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>30 (34.5)</td>
<td>9 (23.1)</td>
<td>.20</td>
</tr>
<tr>
<td>Time to diagnosis, days, median (IQR)</td>
<td>14 (3–33)</td>
<td>24 (10–40)</td>
<td>.053</td>
</tr>
<tr>
<td>Time to diagnosis of ≥3 wk</td>
<td>34 (39.1)</td>
<td>24 (61.5)</td>
<td>.02</td>
</tr>
<tr>
<td>Neurological deficit</td>
<td>14 (16.1)</td>
<td>15 (38.5)</td>
<td>.006</td>
</tr>
<tr>
<td>Concurrent metastatic infection</td>
<td>9 (10.3)</td>
<td>5 (12.8)</td>
<td>.76</td>
</tr>
<tr>
<td>Positive blood cultures</td>
<td>49/79 (62.0)</td>
<td>27/36 (75.0)</td>
<td>.17</td>
</tr>
<tr>
<td>Methicillin-resistant Staphylococcus aureus infection</td>
<td>16 (18.4)</td>
<td>6 (15.4)</td>
<td>.68</td>
</tr>
<tr>
<td>White blood cell count, ×10⁹/L, median (IQR)</td>
<td>11.3 (8.1–14.5)</td>
<td>12.5 (9.1–16.0)</td>
<td>.19</td>
</tr>
<tr>
<td>C-reactive protein, mg/dL, median (IQR)</td>
<td>11.6 (5.5–21.2)</td>
<td>16.1 (6.8–24.6)</td>
<td>.11</td>
</tr>
<tr>
<td>Erythrocyte sedimentation rate, mm/h, median (IQR)a</td>
<td>76 (57–101)</td>
<td>85 (55–106)</td>
<td>.46</td>
</tr>
<tr>
<td>Involvement of ≥3 vertebral bodies</td>
<td>28 (32.2)</td>
<td>15 (38.5)</td>
<td>.49</td>
</tr>
<tr>
<td>Involvement of cervical/thoracic spine</td>
<td>22 (25.3)</td>
<td>21 (53.8)</td>
<td>.002</td>
</tr>
<tr>
<td>Epidural involvementb</td>
<td>53 (60.9)</td>
<td>30 (76.9)</td>
<td>.08</td>
</tr>
<tr>
<td>Paravertebral involvementb</td>
<td>38 (43.7)</td>
<td>22 (56.4)</td>
<td>.19</td>
</tr>
<tr>
<td>Psoas involvementb</td>
<td>28 (32.2)</td>
<td>10 (25.6)</td>
<td>.46</td>
</tr>
<tr>
<td>&lt;6 wk of all antibiotic therapy</td>
<td>13 (14.9)</td>
<td>4 (10.3)</td>
<td>.48</td>
</tr>
<tr>
<td>Spinal instrumentation</td>
<td>36 (41.4)</td>
<td>19 (48.7)</td>
<td>.44</td>
</tr>
<tr>
<td>Type of instrumentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervertebral cage</td>
<td>3 (3.4)</td>
<td>1 (2.6)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Plate</td>
<td>4 (4.6)</td>
<td>1 (2.6)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Screw</td>
<td>36 (41.4)</td>
<td>19 (48.7)</td>
<td>.44</td>
</tr>
<tr>
<td>Rod</td>
<td>34 (39.1)</td>
<td>19 (48.7)</td>
<td>.31</td>
</tr>
<tr>
<td>Bone grafting</td>
<td>37 (42.5)</td>
<td>22 (56.4)</td>
<td>.15</td>
</tr>
<tr>
<td>Surgical approach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>21 (24.1)</td>
<td>7 (17.9)</td>
<td>.73</td>
</tr>
<tr>
<td>Posterior</td>
<td>40 (46.0)</td>
<td>20 (51.3)</td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>26 (29.9)</td>
<td>12 (30.8)</td>
<td></td>
</tr>
<tr>
<td>Among instrumented surgery group</td>
<td>(n = 36)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage of operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-stage operation</td>
<td>14 (38.9)</td>
<td>10 (52.6)</td>
<td>.33</td>
</tr>
<tr>
<td>Two-stage operation</td>
<td>22 (61.1)</td>
<td>9 (47.4)</td>
<td></td>
</tr>
<tr>
<td>&lt;4 wk of post-instrumentation antibiotics</td>
<td>6 (16.7)</td>
<td>4 (21.1)</td>
<td>.72</td>
</tr>
</tbody>
</table>

Data are number (%) of patients, unless otherwise indicated.

Abbreviation: IQR, interquartile range.

a Measured in 110 patients (77 in the no sequelae group and 33 in the sequelae group).

b Either phlegmon or abscess.
Even with these efforts, we found a low rate (6.8%) of infection recurrence for the instrumented surgery group; this was comparable to the rate of 4.8% for the noninstrumented group. There is some evidence that asymptomatic colonization of bacteria on the surface of an implant is common and that clinically relevant recurrence after placement of an implant is rare [20, 21]. In a recent canine model, bacteria were detected on retrieved spinal implants as well as surrounding bone in 80% of animals that underwent instrumentation surgery using a pyrosequencing method; however, no radiological or macroscopic sign of infection recurrence was observed in any animal [21]. Thus, despite the colonization of bacteria on the implant surface in instrumented surgery, these bacteria seem to be controlled by host immunity, and most patients do not experience clinical recurrence. Some may argue that high rates of asymptomatic colonization in spinal implants may give rise to late-onset infection recurrence. Carragee and Iezza observed 24 patients who underwent instrumented fusion for 10-year follow-up periods and found only 1 (4.2%) recurrent infection [19]. In 7 cases of implant removal or autopsy, no case of gross, microscopic, culture, or polymerase chain reaction evidence of residual infection or occult colonization was observed [19].

Recently, Arnold et al reported 23.4% (22/94) treatment failure and 15.3% (13/85) infection recurrence among patients with vertebral osteomyelitis who required spinal instrumentation [22]. The recurrence rate of 15.3% was higher than the rate of 1.7% reported in a recent systematic review [18] and higher than our rate of 6.8%. In the study by Arnold et al, it is noteworthy that 40.5% of the microbiologically diagnosed cases were caused by methicillin-resistant S. aureus (MRSA) [22]. MSSA has been the leading cause of vertebral osteomyelitis in past decades [4]; however, MRSA has become the predominant cause of vertebral osteomyelitis in recent years [15, 16, 23], with more frequent recurrence in MRSA cases than in MSSA cases [15, 23]. In the study by Arnold et al [22], the treatment failure rate was higher in MRSA cases (31.3% [10/32]) than in MSSA cases (13.8% [4/29]; P = .11). Among our patients who underwent surgical treatment, there was a trend toward higher recurrence in MRSA cases (10.7% [3/28]) than in MSSA cases (2.1% [1/47]; P = .14). However, we could not assess this in patients who underwent instrumented surgery because of the small number of MRSA cases.

The optimal duration of antibiotic treatment in vertebral osteomyelitis remains unknown. Although some researchers have reported that patients with vertebral osteomyelitis experience recurrence less frequently when antibiotic therapy was administered for >6–8 weeks [15, 17, 24–26], this association should be evaluated specifically among patients who undergo surgical intervention. Some patients receive foreign instrumentation for spinal stability after surgical debridement and may require therapy of more prolonged duration [27]. In contrast, a shorter duration of antibiotic treatment may have been sufficient in patients who underwent surgical management without instrumentation compared with those who were treated with antibiotics alone, because surgical management usually included radical debridement of infected tissue. In this study, we found a similar protected effect of prolonged antibiotic treatment (≥6 weeks) on recurrence in both surgical debridement alone (noninstrumentation) and surgical debridement with instrumentation (instrumented surgery). Thus, our findings have 2 implications for physicians who encounter patients with vertebral osteomyelitis who require surgical intervention. First, our data suggest that patients who undergo instrumented surgery should receive at least a 6-week course of antibiotic treatment. Second, clinicians should be cautious in shortening antibiotic treatment to <6 weeks in patients who undergo surgical debridement alone until more data are available.

We found no difference in recurrence rates between single- and 2-stage operations and no association between duration of pre-instrumentation antibiotic therapy and recurrence. Our data do not support the notion that a 2-stage operation should be preferred to reduce the supposed risk of recurrence.

Our study had several limitations. First, as in all retrospective studies, the data were incomplete, and some patients were lost to follow-up, which may have introduced unrecognized bias into the results. Second, even in this study, which had a large cohort, we had limited power to identify the optimal duration of antibiotic treatment according to the causative organisms and location of infected vertebra. Third, multivariate analysis for risk factors for recurrence could not be performed because of the small number of recurrence events. Finally, combination therapy with rifampin seems promising for the treatment of prosthetic device-related infections caused by staphylococci [28, 29]. However, we could not evaluate the protective effect of this antibiotic on recurrence because rifampin was used in only 1 patient infected with S. aureus who underwent instrumented surgery.

In summary, placement of spinal instrumentation may not adversely affect the clinical outcomes of patients with HVO who undergo surgical debridement. Thus, concerns about infection recurrence and complications should not prevent the use of instrumentation in the management of vertebral osteomyelitis where spinal stability is needed. Patients who undergo instrumented surgery should receive at least a 6-week course of antibiotic treatment.

Supplementary Data

Supplementary materials are available at Clinical Infectious Diseases online (http://cid.oxfordjournals.org). Supplementary materials consist of data provided by the author that are published to benefit the reader. The posted materials are not copyrighted. The contents of all supplementary data are the sole responsibility of the authors. Questions or messages regarding errors should be addressed to the author.

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Notes

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