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Original Article

Infection with Spinal Instrumentation: A 20-Year, Single-Institution Experience with Review of Pathogenesis, Diagnosis, Prevention, and Management

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Abstract

Objective and Importance: Instrumentation has become an integral component in the management of various spinal pathologies. The rate of infection varies from 2% to 20% of all instrumented spinal procedures. Postoperative spinal implant infection places patients at risk for pseudo-arthrosis, correction loss, spondylodiscitis, and adverse neurological sequelae and increases health-care costs. **Materials and Methods:** We performed a cohort study of 1065 patients who underwent instrumented spinal procedures in our institution between 1995 and 2014. Fifty-one patients (4.79%) contracted postoperative spinal infection. Isolated bacterial species, infection severity, diagnosis/treatment timing, surgical/medical strategy treatment, and patient's medical background were evaluated to assess their relationship with management outcome. **Results:** Multiple risk factors for postoperative spinal infection were identified. Infections may be early or delayed. C-reactive protein and magnetic resonance imaging are important diagnostic tools. Prompt diagnosis and aggressive therapy (debridement and parenteral antibiotics) were responsible for implant preservation in 49 of 51 cases, whereas implant removal noted in two cases was attributed to delayed treatment and uncontrolled infection with implant loosening or late infection with spondylodesis. Infection in the setting of instrumentation is more difficult to diagnose and treat due to biofilm. **Conclusion:** Retention of the mechanically sound implants in early-onset infection permits fusion to occur, whereas delayed treatment and multiple comorbidities will most likely result in a lack of effectiveness in eradicating the infecting pathogens. An improved understanding of the role of biofilm and the development of newer spinal implants has provided insight into the pathogenesis and management of infected spinal implants. It is important to accurately identify and treat postoperative spinal infections. The treatment is multimodal and prolonged.

Keywords: *Biofilm, infection, instrumentation, spinal surgery*

Introduction

Instrumentation, now an integral component in the treatment of numerous spinal pathologies, is correlated with a 2%–20% infection rate.[1-3] The ability to manage postoperative wound infections has become, therefore, more critical and challenging, as they are positively associated with extended hospitalizations, increased morbidity and health-care costs, poorer long-term outcomes, and greater dissatisfaction with the initial operative procedure. Patients with a wound infection after an intervention on the spine have a longer hospital stay, higher mortality, and higher rates of return to the operation room, as compared to those without surgical wound infections.[4] In addition, these infections represent an additional cost to health care as reported in literature.[5] The incidence of surgical-site infections after adult spine surgery varies from 0.7% to 20%.[2,6-26] Although the type of spinal surgery most significantly correlates with infection rates, there are multiple other preoperative, intraoperative, or postoperative factors that also contribute to the risk of infection following spinal fusions such as age, male sex, steroid therapy, diabetes, smoking, American Society of Anesthesiologists (ASA) score, obesity, malnutrition, presence of comorbidities, and previous surgery.[2,4,15,18,27-37]

The risk of intraoperative/postoperative infection is increased by utilizing a posterior surgical approach, applying instrumentation, using allograft, requiring a blood transfusion, and demanding

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longer operation time. The utilization of intraoperative equipment (e.g., fluoroscopy, intraoperative computed tomography [CT], and surgical microscopes) also increases the risk of infection through breaches in sterile technique.[2] Additional strict adherence to proper postoperative wound care is also critical in minimizing the risk of postoperative wound infections.[2,29] Besides the higher invasiveness, the use of instrumentation has an important role in the development of postoperative infections.[3,25,38-40]

Furthermore, it can cause local soft-tissue irritation leading to inflammation and seroma formation that subsequently provides a fertile breeding ground for microorganisms to grow. Adherence of bacteria to the surface of implants is promoted by a polysaccharide biofilm called glycocalyx that acts as a barrier against host defense mechanisms and antibiotics.[3,38,41]

Eradicate infection, obtain a stable wound closure, and maintain the mechanical integrity of fixation and viability of bone grafts for fusion are the goals of the management of infection following the application of spinal instrumentation.[1,5,25,39,42-48] There are numerous influences on the development of postoperative infection that could be divided into unchangeable, strictly patient related, and changeable or procedure related.[3,12,49,50] Conversely, there are no universally accepted protocols for treating deep-wound infections utilizing spinal instrumentation.[2] In this retrospective study, the authors evaluate the preoperative modification of the changeable risk factors, the pathogen, biofilm's impact, infection severity, treatment timing, and implant salvage or removal, identifying their relationship with treatment failure.

Materials and Methods

Patient population

Fifty-one patients with symptoms or signs consistent with infection following the application of spinal instrumentation were identified in a retrospective study of 1065 patients treated in the author's department from January 1995 to December 2014. Diagnosis was made based on at least one of the following: (a) positive results of spine-site cultures, (b) histopathology suggestive of infection, gross intraoperative purulence, the presence of a sinus tract, or a positive Gram stain result from tissue specimens and abnormally high levels of C-reactive protein (CRP). Intraoperative tissue cultures remain the gold standard for identification of the causative microorganism. Magnetic resonance imaging (MRI) with gadolinium enhancement and CT scans improve diagnostic accuracy, and they were used when infection was suspected. The demographics of the patients' preoperative conditions were analyzed. During the period of infection management, the bacteriology, infection severity concerning wound depth with or without myonecrosis, treatment timing from index surgery to infection diagnosis, physiological parameters of host defense, surgical therapies employed, series of imaging studies, and final outcome were investigated. All patients enrolled in this study received clinical and radiographic follow-up for a minimum of 12 months.

Incidence, definitions, and classifications

Posterior and posterolateral spinal instrumentation were recognized with increased infection risk; in contrast, anterior spinal exposures were correlated with reduced risk of infection. Forty-five (88.24%) patients identified with spinal infection had a posterior or posterolateral instrumentation. Six cases (11.76%) with spinal infection had anterior cervical instrumentation; all the cases presented with superficial wound infection.

Early postoperative spinal infections were defined as those occurring within a month after implant placement for fusion, whereas delayed infection were those occurring more than 3 months after the index procedures. The enrolled patients were separated into two groups based on the severity of the infection at the initial debridement and from an anatomical point of view in superficial (without fascial involvement) and deep infections. Clinical outcomes were evaluated based on the quality of fusion, symptomatic improvement, neurological status, functional activities for daily living, and infection eradication. The quality of fusion was assessed on the series of plain and dynamic radiographs at 3, 6, and 12 months of interval, and the lack of a confluent trabecular bone flowing in one of the instrumented segments was defined as a probable nonunion.[18] Failed spinal events after postoperative spinal implant infection were defined as (a) incapacitating motion pain due to implant loosening, (b) pseudo-arthrosis with correction loss, or (c) adjacent segment instability and stenosis revealed on the imaging studies.

Statistical analysis

Patients were categorized into two groups based on an anatomical classification of the spinal infection in superficial and deep locations. Comparison of data was performed using the Wilcoxon signed-rank test in the two groups of the following sections: bacterial species, infection severity, treatment timing, patient's general conditions, and management strategies. $P < 0.05$ was considered statistically significant.

Results

Demographics and risk factors for postimplantation wound infection

The study population comprised 27 males and 24 females. The mean age at index surgery was 61.2 years (range, 48–83 years). They received follow-up for an average of 14.3 years (range, 2.0–18.2 years). Preoperative diagnoses were degenerative spinal stenosis, spinal deformity, or spondylolisthesis in 36 patients and spinal trauma in 15 patients. Destructive tumor or hematogenous spondylodiscitis as original lesions were excluded. The instrumented levels were the lumbar/sacral region in 38, thoracolumbar junction and thoracic region in 7, and upper thoracic/cervical region in 6 cases. No deep wound infection was reported for the cases treated by an anterior approach in the cervical spine including multilevel disc replacement and cases with somatectomy and instrumentation (all the six cases were of superficial wound infections). Patients with late-onset infection (nine patients) had a deep wound infection. All patients received bone grafting (autogenous and/or heterogeneous) for fusion. In two cases (6.66%) 1-level; in 4 cases (13.33%). 2-level; and in 7 cases (23.33%), 3-level arthrodesis were recognized, whereas in 17 cases (56.66%), 4-level or more was recognized as long-level arthrodesis. In terms of risk factors for acquiring postoperative implant spine infection, all the 51 patients had at least one risk factor, reflecting the severity of a patient's underlying diseases/conditions at infection presentation [Table 1]. Concurrently, urinary tract infection was noted in two patients (3.9%) and active infection of any other sites was noted in two patients (3.9%).

Isolated pathogens/microorganisms

Staphylococcus spp. (36 isolates; 70.6%) were the most common culprit, 80% (29 in 36) of which were methicillin resistant. Monomicrobial infection was found in patients with superficial infection than in those with deep infection (97.6% vs. 33.3%). Polymicrobial infection was significantly verified in patients with deep infection. In addition, a high incidence of Gram-negative bacilli was identified in patients presenting with deep-site and polymicrobial infections.

Management strategies in early- versus late-onset infections

Early-onset infection (range, 3–30 days) was diagnosed in 42 patients, and the other nine patients suffered from late-onset infection (range, 3–12 months), including two cases with delayed treatment (range, 3–8 months). Gram-positive bacilli and monomicrobial infection ($P < 0.01$) were significantly found in patients presenting with early-onset infection [Table 2]. In contrast, the organisms isolated from late-onset infection were coagulase-negative *Staphylococcus* in three, *Escherichia coli* in three, *Pseudomonas aeruginosa* in one, and sterile in two cases. Diagnostic presentation of 42 patients with early-onset infection was wound dehiscence in 30 (71.42%), back pain and fever in 16 (38%), fever in 10 (23.8%), and leg pain in 3 (7.14%) cases. Among them, implant preservation was significantly achieved with solid fusion in 40 patients (95.23%, $P < 0.01$), with probable nonunion in two patients (4.76%). In contrast, of nine patients with late-onset infection, solid union developed in 7 patients (77.7%), whereas loosened screws, pseudo-arthrosis, and adjacent segment instability were identified in the remaining two patients (22.2%) who underwent implant removal [Table 3].

Table 1: Risk factors of the 51 patients for acquiring postoperative wound infection after spinal instrumentation

Risk factors	Number of patients (%)
Elderly (age >70 years)	10 (19.6)
Previous spinal surgery	4 (7.8)
Trauma (ISS >18)	15 (29.4)
Body mass index >30	5 (9.8)
Cauda equina syndrome	3 (5.9)
Diabetes mellitus	12 (23.5)
Cardiovascular disease	16 (31.4)
Liver diseases	5 (9.8)
Chronic pulmonary diseases	6 (11.8)
Steroid use	10 (19.6)
Concurrent active infection: Urinary tract	2 (3.9)
Concurrent active infection: Pneumonia	2 (3.9)

ISS – Injury Severity Score

Implant preservation versus removal

Successful implant salvage was achieved in 96% (49 in 51) of patients, including 36 without debridement and 9 with only one procedure. Adjunctive procedures were performed including antibiotic-impregnated beads used in 30 patients and wound-packed dressing for delayed closure in 11 patients. All the 51 patients underwent intravenous and/or oral administration of antibiotics based on the results of microbiological cultures. Of the 49 cases with implant preservation, solid fusion was achieved significantly in 46 patients (93.88%, $P < 0.05$) and probable nonunion was observed in 3 patients (6.12%), without correction loss or pedicle screw loosening. On the other hand, two patients underwent implant removal due to significantly developing pseudo-arthrosis with correction loss, loosened screws inducing incapacitating pain, and extensive tissue necrosis deteriorating septicemia [Table 3]. In terms of contributing to the success of implant preservation for solid fusion, early-onset treatment was recommended ($P < 0.01$), but the number of employed debridement alone was not significantly correlated. Delayed treatment for infection >3 months significantly led to implant removal and a higher number of failed spinal events, irrespective of the patients' various risk factors ($P > 0.05$).

Clinical outcomes and surgical revision

Symptoms, neurological status, and daily activity level of the 51 patients were evaluated at 1- and 2-year follow-up. Patients with severe trauma and preexisting neurological deficits (Injury severity score [ISS] >18) had a higher rate of poor clinical outcomes than patients with degenerative spinal diseases in postoperative wound infection after spinal instrumentation. Two of the 51 (3.92%) patients exhibited pseudo-arthrosis with correction loss and nonunion. All of them underwent reconstruction surgery for the failed spine

Table 2: Pathogens isolated from superficial and deep wound infection in the 51 patients after surgery for spinal instrumentation

Pathogens	Type of wound infection, superficial wound infection (42 patients)	Type of wound infection, deep wound infection (9 patients)	*P**
Monomicrobial	41	3	<0.01
Polymicrobial	1	4	
Gram positive	35	3	<0.01
Staphylococcus aureus (MRSA resistance included)	30	3	
Staphylococcus epidermidis (MRSA resistance included)	3	0	
Enterococcus faecalis	1	0	
Gram negative	7	4	
Escherichia coli	4	3	
Enterobacter cloacae	3	0	
Pseudomonas aeruginosa	0	1	
Fungus	0	0	

**P* level for comparisons of data between superficial wound infection and deep wound infection, using the Wilcoxon signed-rank test. MRSA – Methicillin-resistant *Staphylococcus aureus*

Table 3: Microbiological and clinical reports of the 51 patients with early- or late-onset wound infection after spinal instrumentation

Reports	Early-onset infection (42 patients)	Late-onset infection (9 patients)	*P**
Microbiological reports			
Monomicrobial	41	3	<0.01
Polymicrobial	1	4	
Sterile	0	2	
Gram positive	35	3	<0.01
Gram negative	7	4	
Clinical reports			
Implant preservation and solid fusion	42	7	<0.05
Implant preservation and nonsolid fusion	0	0	
Correction loss/pedicle screw loosening/nonfusion	0	2	
Implant removal	0	2	
Revision surgery with instrumentation	0	2	

**P* level for comparisons of data between patients with early- and late-onset wound infection, using the Wilcoxon signed-rank test

following implant removal for infection control, imaging studies, and a survey of general conditions. These two symptomatic patients had a combination of failed events, such as pseudo-arthrosis with correction loss and peridiscal erosion of the loosened screws without spondylodiscitis of adjacent level. They underwent long-level posterior instrumentation with a heterologous bone graft. All of them were favorably cured of pseudo-arthrosis, screw peridiscal erosion, and adjacent segment problems. At an extended 2-year follow-up, all patients improved back symptoms, although preexisting neurological deficits were maintained.

Discussion

Postoperative spinal wound infection is a potentially devastating complication after spine procedures. Despite the development of prophylactic antibiotics and advances in surgical technique and postoperative care, wound infection continues to compromise patients' outcome after spinal surgery.[3,25] This kind of infection places the patient at risk for pseudo-arthrosis, adverse neurologic sequelae, chronic pain, and even death.

A study by Veeravagu *et al*.[4] shows that patients with a wound infection after an intervention on the spine have a longer hospital stay, higher mortality, and higher rates of return to the operation room, as compared to those without surgical wound infections. In addition, these infections represent an additional cost to health care.[3,5]

Postoperative wound infection after spinal instrumentation remains a serious complication after instrumentation for fusion. The worst case scenarios in managing infected implants are bacteremia; complex medical comorbidities; and poor outcomes, such as unstable spine, weak fusions, and loosened pedicle screw inducing spondylodiscitis, epidural abscess, and stenosis.[1,5,14,15,25,43,44,48,51-56]

Controversy exists in published reports as to how the underlying conditions influence a patient's ability to control infections, the extent to which delayed treatment predisposes a patient to infection recurrence, and whether spinal instability or nonunion can be repaired [Table 4].[1,5,15,25,42-44,47,48,53,57]

The present review revealed the importance of infection severity, bacteriology, treatment timing, and underlying diseases for implant salvage.[1,5,25,42-44,48,53,58] Evaluating patients with these variables would help guide the management strategy, in order to obtain healing, determine the levels of aggressive treatment, and achieve good outcomes. Prevention of wound infection after spine instrumentation remains the main goal of our daily practice, through the identification and correction of the surgical and nonsurgical factors contributing to spinal infections [Table 5].

Thalgott *et al*.[5] stratified hosts' physiological response and infection severity based on the bacteriology and extent of bone and soft-tissue structural involvement. Chen *et al*.[1] categorized patients' underlying diseases and their nutritional status as items of clinical assessment. Xing *et al*.[55] reviewed evidence-based independent risk factors between 1998 and 2012 and identified six strong factors, including obesity, longer operation times, diabetes, smoking, previous surgical-site infection, and types of surgical procedure. In our study, patients with severe trauma (ISS >18), neurological deficits, long-level (≥4) instrumentation, and delayed treatment (≥3 months) had poorer outcomes. Delayed treatment for infection mostly led to implant removal and failed spinal events, irrespective of patients' various risk factor scoring. No malnutrition status or immunosuppressed status was detected among the patients with wound infection in our series.

Conventionally, the managment of the postoperative wound infection after spine instrumentation protocol is aggressive debridement and irrigation until the wound is sufficiently clean for closure. Kasliwal *et al*.'s[2] review demonstrated how the management of infection after spinal instrumentation is controversial and recommended careful consideration of the following two most critical variables. First, the duration of the antimicrobial therapy, and second whether or not the implants should be removed. Treatment paradigms have evolved greatly over the past 10–15 years,

Table 4: Data comparison of patients with wound infections after spinal instrumentation in the present study and literature review

Data	Other studies	Present study
Early-onset infection (average days)	16-22.9	13
Late-onset infection (average months)	11-20	5
Risk factors scoring (average)	1.2-2.6	14
Superficial wound infection (percentage of patients)	Variable to 74.5	82.3
Deep wound infection (percentage of patients)	Variable to 24.5	17.7
Debridement (average times)	1.5-4.7	1
Adjacent discitis (%)		
Implant preservation and solid fusion (%)	Variable to 80.4	96
Delayed treatment (%)	15.7	17.6
Correction loss/pedicle screw loosening/nonfusion (%)	13.6-35	3.9
Implant removal (%)	19.6	3.9
Revision surgery with instrumentation (%)	15.7	3.9
Mortality (%)	10-13.9	0
Follow-up duration (average years)	Variable to 7.3	14.3

Table 5: Risk factors for surgical wound infection after spinal instrumentation

Risk factor type	Patient-specific factors	Surgery-specific factors
Preoperative	Advanced age	Preoperative hospital stay
	Male sex	Prior surgery
	Steroid therapy	Trauma
	Diabetes mellitus	Tumor/malignancy
	Concurrent active infection	
	Tobacco/alcohol use	
	Cardiopulmonary diseases	
	High ASA score	
	Obesity	
	Liver diseases	
	Malnutrition	
	Immunocompromised state	
Intraoperative		Length of surgery >5 h
		Posterior approach
		Number of levels operated with instrumentation
		Implant material
		Use of allograft
		Blood transfusion
		Not accurate hemostasis/absence of drainage
		Use of cell savers
		Use of microscope/C-arm/O-arm
		Open surgery versus mini-invasive
		Staged surgery
Postoperative	Urinary/fecal incontinence	CSF leak
	Poor wound care	Drainage <24 h
	Postoperative ICU stay	

Present study and literature review. ASA – American Society for Anesthesiologists; ICU – Intensive care unit; CSF – Cerebrospinal fluid and the present recommendation is to preserve rather than remove the spinal instrumentation in the majority of the cases, as in our review, we demonstrate that only 2 (3.9%) of the 51 patients identified with infection after spinal instrumentation underwent implant removal. However, the timing of infection after surgery (early vs. delayed) can be an important guiding factor determining the management choice,[1,2,6] as in our series, we highlight that two of the nine patients with delayed diagnosis of infection underwent implant removal, in contrast with no case of revision surgery in the group of 42 patients with early-onset diagnosis and treatment.

The utility of clinical routes, laboratory tests, and imaging studies in arriving at a presumptive diagnosis of infection and commencement of early implant salvaging is stressed.[1-3,37,53,59] Laboratory studies are an important part of evaluation of infected spinal implants. Erythrocyte sedimentation rate (ESR), CRP, and total leukocyte count (TLC) are routinely ordered when there is a suspicion of a postoperative infection.[2] ESR and CRP values are considered more useful than TLC in the detection of spinal infection.[60] For each variable, a rising trend in the postoperative period is more suggestive of infection than a single abnormal value as these markers are routinely elevated in the early postoperative period even without infection.

Plain radiography, CT, and MRI are routinely ordered when an infection is suspected. Early implant loosening, rapid loss of adjacent-level disc height, and abnormal soft-tissue swelling are indirect markers of infection on plain X-rays but are often not seen until a few weeks after the onset of infection. CT delineates hardware position and bony changes more accurately than plain radiographs, and CT also shows fluid collections. MRI scans with and without contrast are of great value in diagnosing discitis, osteomyelitis, and epidural abscesses after spinal surgery. However, it is not often possible to distinguish a sterile seroma from a purulent collection utilizing early contrast-enhanced CT or MRI studies following the implantation of spinal instrumentation.[2,8]

A key factor in deciding whether or not to remove spinal instrumentation relates to biofilm. Biofilm is defined as a microbial-derived sessile community characterized by cells that are embedded in a matrix of extracellular polymeric substances, which they produce.[2] Common organisms such as *Staphylococcus aureus*, coagulase-negative *Staphylococcus,* and *Propionibacterium* implicated in postoperative infections after spinal instrumentation have a predilection for biofilm formation.[2,14] Laboratory investigations document that biofilms may develop within 5–6 h after bacterial inoculation, and the age of the biofilm has major clinical implications related to its tenaciousness and antimicrobial susceptibility.[2] Early surgical intervention of acute infections with wound irrigation/debridement is more readily able to disrupt biofilm formation and facilitate penetration of systemic antimicrobials to allow for resolution of the infection while preserving the instrumentation and stability. This concept is supported by the clinical experience,[2,43,60] also in our study cases, and demonstrates that expedient treatment of early postoperative infections results in higher rates of infection resolution, preservation of instrumentation, and better clinical outcomes.

Delayed wound infection often requires removal or replacement of the instrumentation.[2,6,44] Late-onset infections are caused primarily by organisms known to produce biofilm such as coagulase-negative Staphylococci. Similar to the management of other bone and joint infections involving prosthesis, this makes the eradication of infection difficult without foreign body removal. Retention of spinal instrumentation after delayed infection is fraught with more morbidity and less success. Ho *et al*.[61] reported the strong propensity for recurrence of infection (up to 50%) in the absence of implant removal.

Prevention of spinal implant infection is a major goal of daily practice. Identification of multiple preoperative, intraoperative, or postoperative risk factors [Table 5] that contribute to infections following instrumented spinal fusions helps decrease the infection risk. Barker[7] utilizing pooled data from six randomized controlled trials documented a lower incidence of infection following spine surgery, utilizing antibiotic prophylaxis. They recognized the efficacy of a single preoperative dose of a prophylactic antibiotic providing Gram-positive coverage. Notably, no other findings proved significant such as the antibiotic utilized, the dosage protocol, the schedule for redosing antibiotics, and the duration of postoperative prophylactic antibiotics. The "no shaving" data for spinal and other procedures and the use of sophisticated air filtering have been positive.[2,28] Ho *et al*.[62] support the benefit of closed suction drainage to prevent acute, postoperative, surgical-site infection after spine surgery. In authors' practice for spine surgery (with or without instrumentation), antibiotic prophylaxis is administrated <60 min before incision and a half dose of the same antibiotic is administrated if the surgery is longer than 4 h. No postoperative prophylactic antibiotic is recommended. Suction drainage is placed always for spine fusion cases and is removed between 12 and 24 h from surgery for early mobilization of the patient (when it is possible based on neurological/clinical conditions).

The risk of intraoperative/postoperative infection is increased by utilizing allograft, requiring a blood transfusion, necessitating longer operation time, and demanding multiple intraoperative equipment (surgical microscopes, fluoroscopy, and intraoperative CT). The authors advocate steady, fast surgeries by well-trained spine surgeons, with careful hemostasis. All the personnel present in the operating room should be educated to minimize any contact with the intraoperative equipment due to the possibility of breaches in sterile technique.

Care must be taken also to the preoperative (age of the patient, presence of comorbidities, diabetes, smoking, steroid therapy, and ASA score) and postoperative factors such as strict adherence to proper postoperative wound care. Preoperative risk factors should be carefully searched and treated wherever is feasible before surgery. For whatever reason patients with such risk factors undergoing surgery for spinal fusion, they should be under strict control to detect the early symptoms of wound infection due to early diagnosis and treatment.

Surgical debridement and irrigation, frequently with a wound drain, has been an important means of treating early postoperative infections following the implantation of spinal instrumentation.[2,47] Multiple debridement may be required for successful eradication of infection. In our study of 51 patients identified with wound infection following spinal surgery for fusion, nine of them had one procedure of surgical debridement. All the six cases of spinal infection for anterior cervical instrumentation were of superficial wound infection and were treated successfully with wound-packed dressing. Poorly vascularized surgical sites or significant wound defects may mandate the use of complex flaps for reconstruction.[2] In addition to surgical debridement and postoperative antimicrobial therapy, the use of suction and/or irrigation systems, antimicrobial beads, or vacuum-assisted closure devices may also improve the outcomes of early infection after the placement of spinal instrumentation in selected patients. Closed suction drainage usually negates the need for secondary closures, and excellent reports have been published for these irrigation systems.[2,5,43,45,48]

Antimicrobial choice should be made optimal based on the culture results and antibiotic sensitivity of the organisms. There is a general agreement, and is also authors' common practice, on the need for 6–8 weeks of parental therapy, although data addressing the need for and duration of long-term oral suppressive antibiotic therapy are lacking.[2] The mean duration of antibiotic therapy may be much longer as reported in the study by Kowalski *et al*.,[44] who found that with early postoperative infections, treatment with long-term suppressive antibiotic therapy was associated with higher chances of eradicating infections and retaining implants versus those who did not receive suppressive therapy.

The limitations of this retrospective study include diverse indications for instrumented fusion and the lack of novel strategies for salvaging implants. Despite the limitations, the risks of delayed treatment and multiple comorbidities had been proven to anticipate a low percentage of effectiveness in eradicating infecting pathogens. In postoperative spine infections following instrumentation for fusion, we preserve implant for stabilization and fusion to achieve the same functional outcomes as achieved in noninfected cases.[1,60] However, when loosened screws cause peridiscal erosion and incapacitating motion pain, and uncontrol infection implant, removal is recommended. Reconstruction of the spine is feasible and should be taken following infection control in selected patients.

Conclusion

Despite all the measures to reduce the incidence of infections following surgery for spinal instrumentation, there remains a dangerous complication. Prevention is the best way to solve the problem. The risk factors of each patient should be analyzed, and the exchangeable ones should be eliminated. Training and continuous education in spine surgery are mandatory to eliminate the intraoperative and postoperative risk factors. It is important to recognize the clinical symptoms and signs of postoperative spinal infections and confirm the diagnosis with appropriate laboratory and imaging studies. Prompt, aggressive debridement coupled with utilizing the correct antibiotic therapy (typically 6–8 weeks of intravenous antibiotics) and, in some cases, chronic suppressive antibiotic treatment have yielded the most successful results. Instrumentation can usually be preserved in patients with early infections, but instrumentation removal should be considered for infections presenting in a delayed fashion (from 3 months to years). Patients should be adequately followed up for 1 postoperative year to ensure that the infection has been fully eradicated. Further, spinal reconstruction is feasible in the absence of solid arthrodesis and in the presence of mechanical instability related to the infection sequelae. Emerging techniques are increasingly preventing the formation of biofilm on instrumentation, facilitating the removal of biofilm, and increasing the culture yield of biofilms on implant surfaces. In future, implant sonication provide cultures for direct identification of active or persistent biofilm, whereas the introduction of enzymes that dissolve the biofilm matrix and quorum-sensing inhibitors that increase biofilm susceptibility to antibiotics may further help manage postoperative infections. In addition, changes in antibiotic prophylaxis to prevent postoperative infections following spinal instrumentation remain active areas for further investigation.

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Conflicts of interest

There are no conflicts of interest.

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