ORIGINAL ARTICLE
Hip Pelvis 26(4): 227-234, 2014
http://dx.doi.org/10.5371/hp.2014.26.4.227

Print ISSN 2287-3260
Online ISSN 2287-3279
Hip & Pelvis

Efficacy of Debridement for Early Periprosthetic Joint Infection after Hip Arthroplasty

Jong Hoon Kim, MD, Sung Kwang Chun, MD, Yong Cheol Yoon, MD, Devendra Lakhotia, MS, Won Yong Shon, MD

Department of Orthopedic Surgery, Korea University Guro Hospital, Korea University College of Medicine, Seoul, Korea

Purpose: In early prosthetic joint infection after hip arthroplasty, debridement with prosthesis retention may be performed for implant salvage, but the reported success rates are highly variable. Hence we reviewed the outcome of radical debridement and retention of prosthesis using established diagnostic criteria and surgical procedures in relation to significant variables including clinical characteristics, pathogenicity, and antibiotic treatment.

Materials and Methods: We retrospectively reviewed 20 patients (11 men and 9 women) with early prosthetic joint infection after unilateral hip arthroplasty, treated by radical debridement with retention of prosthesis from January 2000 to May 2011. Average follow-up period was 55 months (12-178 months). The outcome was evaluated and analyzed based on recurrence of infection and clinical (Harris hip score) and radiological criteria.

Results: Pathogens were isolated from 11 hips (methicillin-resistant *Staphylococcus aureus* [MRSA] in three, methicillin-resistant *Staphylococcus epidermidis* [MRSE] in two, methicillin-sensitive *Staphylococcus aureus* [MSSA] in one, *Acinetobacter baumannii* in two, *Enterococcus faecalis* in two patients, and *Enterococcus, Citrobacter* species in one). The mean duration of antibiotic administration was 43.5 days. Recurrence of infection was not observed in any case. Average Harris hip score was 91 points at the last follow-up. Revision surgery was not required for any reason including implant failure. Dislocation occurred in two hips after debridement and was treated conservatively.

Conclusion: Radical debridement with prosthesis retention is an effective procedure for early prosthetic joint infection after hip arthroplasty in carefully selected patients and with early diagnosis.

Key Words: Hip arthroplasty, Prosthetic infection, Debridement

Submitted: November 7, 2013 1st revision: December 30, 2013
2nd revision: April 3, 2014 3rd revision: August 7, 2014
4rd revision: September 24, 2014 Final acceptance: October 2, 2014

Address reprint request to
Won Yong Shon, MD
Department of Orthopaedic Surgery, Korea University Guro Hospital, 148 Gurodong-ro, Guro-gu, Seoul 152-703, Korea
TEL: +82-2-2626-1163 FAX: +82-2-2626-1164
E-mail: Shonwy@hotmail.com

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Prosthetic joint infection (PJI) is one of the major complications following arthroplasty. Optimal management of PJI is not limited to the treatment of joint infection alone, but also includes the maintenance of normal joint function along with improving quality of life.

Unlike other focal infections, PJI is particularly difficult to treat. Microorganisms form a biofilm on the metal surface of the implant, which interferes with antibiotic penetration and promotes resistance. The success of PJI treatment is dependent on the elimination of these

Copyright © 2014 by Korean Hip Society

Hip Pelvis 26(4): 227-234, 2014

Table 1. Patient Information (n=20)

Age (yr)	Sex	Comorbidity	Indication	Arthroplasty
83	Male	DM, HTN, stroke	Femur neck Fx	Bipolar
76	Female	HTN, stroke Angina,	Femur neck Fx	Bipolar
67	Female	bipolar II disorder, parkinsonism	Femur neck Fx	Bipolar
73	Male	Hypothyroidism, dementia	Femur neck Fx	Bipolar
83	Female	None	Femur neck Fx	Bipolar
87	Female	HTN	Femur neck Fx	Bipolar
79	Female	None	Femur neck Fx	Bipolar
52	Female	None	ONFH	THRA
68	Male	Alcoholic hepatitis	ONFH	THRA
77	Male	HTN	ONFH	THRA
62	Male	COPD	Femur neck Fx	THRA
65	Male	DM	ONFH	THRA
41	Male	None	ONFH	THRA
34	Male	None	ONFH	THRA
49	Female	Cerebral palsy	Dysplastic hip	THRA
68	Male	HTN, angina	Secondary OA	THRA
66	Female	None	Aseptic loosening	Revision THRA
66	Male	Intra-cranial hemorrhage	Aseptic loosening	Revision THRA
64	Male	DM	Aseptic loosening	Revision THRA
71	Male	No	Component dissociation	Revision THRA

DM: diabetes mellitus, HTN: hypertension, COPD: chronic obstructive pulmonary disease, Fx: fracture, ONFH: osteonecrosis of femoral head, OA: osteoarthritis, Bipolar: bipolar hemiarthroplasty, THRA: total hip replacement arthroplasty.

biofilm-dwelling microorganisms[1,2]. The primary surgical interventions performed to manage PJI are, either removal of the prosthesis to eliminate the biofilm, which may be followed up with a revision surgery later, or retaining the prosthesis and administration of biofilm active antibiotics along with radical debridement[3].

Compared to other treatment options for early PJI, debridement with prosthesis retention is relatively simpler and has lesser morbidity, shorter hospital stay, and lower costs compared to revision surgery[4]. However, the reported success rates of debridement with prosthesis retention and long-term antibiotics is highly variable (21-89%)[4-10]. Hence, in the current study, we evaluated the outcome of radical debridement with retention of prosthesis for early PJI after hip arthroplasty.

MATERIALS AND METHODS

1. Subjects

Twenty patients who developed early PJI following unilateral hip arthroplasty from January 2000 to May 2011 in Korea University Guro Hospital (Seoul, Korea) and were managed with radical debridement and retention of prosthesis were selected for the study. A retrospective chart review was performed to obtain the relevant details. There were 11 men and 9 women in the study sample with a mean age of 67.4 years (41-87 years). They had undergone either minimally invasive or conventional posterolateral approach for arthroplasty (Table 1). The various types of arthroplasties that were employed are listed in Table 2. All patients were followed-up for at least one year. The mean follow-up was 55 months (12-178 months). There were four patients with hypertension, three with diabetes mellitus, three with

Table 2. Type of Total Hip Replacement Arthroplasty (THRA)

Type of surgery	Hip (n)
Cemented bipolar hemiarthroplasty	4
Non-cemented bipolar hemiarthroplasty	3
Non-cemented THRA	7
Hybrid type THRA	2
Non-cemented revision THRA	2
Hybrid type revision THRA	1
Revision THRA using acetabular roof ring	1

history of cerebral hemorrhage and stroke, and one each with hypothyroidism, alcoholic liver disease and cerebral palsy (Table 1). Overall, patients were relatively healthy.

2. Diagnosis

We operationally defined an acute infection as fulfilling the following two conditions. The first condition consisted of clinical characteristics: (a) symptoms (pain, swelling, erythema and fever) with associated signs (persistent wound drainage or a sinus tract at operating wound); (b) isolation of microorganism from the tissue or wound discharge; (c) abnormal laboratory parameters of erythrocyte sedimentation rate (ESR) >30 mm/h and C-reactive protein (CRP) >5.0 mg/L (measured by nephelometry). The second condition was gross purulence surrounding the prosthesis at the time of radical debridement, or histological specimens of intra-articular tissue showing more than 10 polymorphonuclear leukocytes per high-power field in ≥ two frozen sections or more than 5 in ≥ three sections at high magnification (×400)[11-13]. Coventry classification for early acute infection was used to categorize the cases[14,15].

3. Surgical Procedure and Postoperative Management

Once early PJI was diagnosed, radical debridement was performed with retention of prosthesis after informed consent from the patient. Conventional posterolateral approach was used through the previous incision and all necrotized soft tissue was removed including the extrusion from the hip joint and sinus tracts. Aggressive debridement of infected tissue was performed from all sites (e.g., acetabular and femoral sites) and 3-6 L of normal saline was used for irrigation using the pulsatile lavage system. The femoral heads and acetabular liners were either replaced or reused after submerging in 97% ethanol for 10-15 minutes[16,17]. The surgical site was packed with gauze soaked in 10% povidone-iodine solution for 5-10 minutes followed by repeat irrigation with 3 L of normal saline. The incision was closed after placement of a suction drain[18].

Pre-debridement, antibiotics were withheld, in order to minimize development of tolerance in the organisms and to promote bacterial growth in cultures from intraoperative specimens. However, relevant intravenous antibiotic treatment was initiated immediately after intraoperative samples were obtained, in consultation with an infectious disease specialist and it was further modified according to microbiological results.

In patients with normal laboratory parameters (CRP and ESR, checked 2-3 times per week), the duration of intravenous antibiotic treatment was 4 weeks after debridement. However, antibiotic treatment was continued in patients with abnormally high CRP levels until it returned to normal levels.

4. Clinical and Radiological Evaluation

The clinical outcome was assessed using the Harris hip score (HHS) at the final follow-up. Radiographic images taken post-surgery and at final follow-up were compared. Standard radiographs included an anteroposterior (AP) view of the pelvis and lateral views of the proximal femur. For the assessment of radiographs, the acetabulum was divided into three zones on the AP view, as described by DeLee and Charnley[19]. Acetabular component loosening was defined as a change in the acetabular component position, component migration >5 mm[20], screw fracture, or complete radiolucency of ≥2 mm at the bone-implant interface in any zone. The femoral stem stability was categorized into fixation by bone ingrowth, stable fibrous fixation, or unstable prosthesis according to Engh's criteria[21]. The changes in the alignment and subsidence of the cementless femoral components were measured; ≥3° of valgus or varus and ≥5 mm longitudinal change were considered as loosening[22]. Loosening of the cemented femoral stem was defined as the appearance of a progressive radiolucent line or radiolucency >1 mm in all zones, or the presence of continuous subsidence or migration of the femoral stem[23]. Osteolysis was diagnosed when cystic radiolucency (>2 mm) was observed after the surgery[24]. Osteolysis of acetabular and femoral parts were examined in the zones described by DeLee and Charnley[19], and Gruen et al.[23] respectively.

Successful treatment of infection was defined as 1) absence of clinical symptoms (e.g., pain, swelling, erythema, and wound discharge), 2) normal laboratory parameters (ESR and CRP levels), and 3) no radiological failure. Failure was defined as clinical signs of PJI, symptoms including persistent pain and abnormal laboratory parameters necessitating reoperation.

Statistical analysis was performed using Mann-Whitney U-test and Spearman's correlation coefficient

tests (IBM SPSS Statistics ver. 20.0, 64 bit for Windows; IBM Co., Armonk, NY, USA). *P*-values less than 0.05 were considered significant.

RESULTS

1. Outcome of Treatment

Debridement with retention of the prosthesis was performed at an average of 31.3 days (18-48 days) after hip arthroplasty. CRP and ESR returned to baseline after averages of 35.0 days (19-105 days) and 63.5 days (29-156 days) respectively. Mean hospitals stay was 50.6 days (23-85 days) after the surgery and there was no recurrence of infection (Table 3).

Table 3. Treatment Outcome

Treatment outcome	Duration (day)
Recovery to normal range (ESR)	63.5 (29-156)
Recovery to normal range (CRP)	35.0 (19-105)
Interval between arthroplasty and debridement	31.3 (18-48)
Hospital days	50.6 (23-85)

Values are presented as average (range).
ESR: erythrocyte sedimentation rate, CRP: C-reactive protein.

2. Microbiological Results

The pathogens isolated were methicillin-resistant *Staphylococcus aureus* (MRSA) in three patients, methicillin-resistant *Staphylococcus epidermidis* (MRSE) in two patients, methicillin-sensitive *Staphylococcus aureus* (MSSA) in one patient, *Acinetobacter baumannii* in two patients, *Enterococcus faecalis* in two patients, and *Enterococcus* and *Citrobacter* species in one patient. No pathogen was isolated from the remaining patients (9 hips).

3. Antibiotic Treatment (Duration and Type)

After radical debridement, vancomycin, vancomycin+ aminoglycoside or vancomycin+ levofloxacin were given. In patients with isolated and sensitivity-tested pathogens, other antibiotics were used either alone or in combination as per sensitivity (e.g., ciprofloxacin, ampicillin, sulbactam, teicocin, tazocin, and rifampin). The average duration of intravenous antibiotic administration in all patients was 43.5 days (28-62 days), in patients with isolated pathogens alone, it was 46 days (35-62 days), and in those without an isolated pathogen it was 35.5 days (28-60 days) (Table 4). The

Table 4. Isolated Pathogen, Antibiotics Used and Treatment Duration

Causing microorganism	Antibiotics	Duration (day)
MSSA	Vancomycin, Teicocin	36
MRSA	Vancomycin, Aminoglycoside	53
MRSA	Vancomycin	42
MRSA	Cephalosporin, Vancomycin	52
MRSE	Vancomycin, Ciprofloxacin	46
MRSE	Vancomycin, Unasyn, Ertapenem	42
Acinetobacter baumannii	Vancomycin, Teicocin, Levofloxacin	58
Acinetobacter baumannii	Vancomycin, Aminoglycoside	50
Enterococcus faecalis	Vancomycin, Ertapenenm	39
Enterococcus faecalis	Vancomycin, Ciprofloxacin	55
Citrobacter species	Vancomycin, Aminoglycoside	42
No growth	Vancomycin, Tazocin	40
No growth	Vancomycin	35
No growth	Vancomycin, Levofloxacin, Rifamfin	32
No growth	Vancomycin	29
No growth	Vancomycin	38
No growth	Vancomycin	38
No growth	Vancomycin	35
No growth	Levofloxacin	42
No growth	Vancomycin	62

MSSA: methicillin-sensitive *Staphylococcus aureus*, MRSA: methicillin-resistant *Staphylococcus aureus*, MRSE: methicillin-resistant *Staphylococcus epidermidis*.

duration of antibiotic administration was significantly longer in patients with isolated pathogens compared to others (P=0.018). In two patients with continued abnormal CRP levels, antibiotic administration was discontinued after two months as suggested by infectious disease specialists.

4. Clinical and Radiological Outcomes

None of the patients had surgery-related gait abnormalities during the follow-up. The average HHS at the last follow-up was 91 points (82-98 points). On radiologic examination, there was no osteolysis, change of acetabular component position or subsidence of femoral stem. None required revision surgery for fixation failure.

5. Complications

One patient developed temporary nephrotoxicity after the administration of vancomycin; hence, teicomycin was alternatively used. Two patients died two and three years after the surgery, due to medical conditions unrelated to PJI. Two had hip dislocation after radical debridement and were treated conservatively after closed reduction.

DISCUSSION

The Coventry classification modified by Senthi et al. for postoperative infections in hip arthroplasty describes the following general stages[14,15]. The first and second stage comprises acute infections occurring within 6 weeks and delayed chronic presentations, respectively. The third stage refers to infections on prosthesis with previously well-maintained function and the fourth stage is a positive for microbiological isolate during the aseptic revision of arthroplasty.

Our study shows that radical debridement with prosthesis retention and long-term antibiotics had a high success rate (100%) for early PJI. The HHS was 91 points (82-98 points) at the last follow-up. No robust treatment guidelines currently exist for early PJI after arthroplasty. Antibiotic therapy alone does not have favorable results and are reserved for patients in very poor health and surgical treatment is not a viable option[3]. Clinical outcomes of other treatment options such as early joint centesis are questionable[25,26].

The surgical treatments that are available include centesis of the joint, debridement, one, and two-stage reimplantation[3]. Two-stage reimplantation is a commonly performed procedure in chronic infection with favorable success rates. However, it requires 1) long-term treatment; 2) two complicated surgeries (removal of well-fixed prosthesis and reimplantation), which increases the risk of complications such as loss of bone stock, soft tissue deformation, and perioperative fractures; and 3) long-term hospitalization, which places considerable burden on both the patient and the hospital[4,27].

The effectiveness of radical debridement with retention of prosthesis in patients with early PJI has been questioned due to its variable success rates across studies[28]. Brandt et al.[5], Koyonos et al.[29], and Odum et al.[30] reported low rates (36.3%, 31% and 36% success rate respectively) of infection control and hence suggested that radical debridement has limited utility and should be performed only in certain situations. In contrast, Meehan el al.[31] reported a high success rate of 89% in 19 cases of streptococcal infection. Vilchez et al.[32], Tsukayama et al.[6], Barberán et al.[33], van Kleunen et al.[34], Bassetti et al.[35], and Choong et al.[9] have reported success rates of 75.5%, 71%, 83%, 72%, 80% and 78% respectively.

Several factors influence the course of postoperative infection including host conditions, type of pathogen, antibiotics sensitivity, and surgical approach. Signs of infection, longer duration of symptoms, poor status of soft tissues and antibiotic resistance of pathogens are known to play a major role in failure[5,33,36,37].

The timing of radical debridement in relation to outcome is a commonly discussed factor. It has been reported that early radical debridement is important to ensure good treatment outcomes. Brandt et al.[5] reported a higher risk of failure if radical debridement was performed after 2 days of infection. In another study, Tattevin et al.[36] reported that the treatment was successful when the surgery was performed within an average of 4.85 days and failed if it was after 54.2 days. Marculescu et al.[37] reported overall 60% success rate and when the surgery was done after 8 days of infection, the success rate dropped to 49%. In another study, Crockarell et al.[8] concluded that the debridement with retention of prosthesis is successful treatment when performed within 2 weeks. Barberán et al.[33] showed that the success rate of radical debridement performed within a month after the onset of infection was as high as 84.5%, but significantly lower (33.4%) if it was after 6

Hip Pelvis 26(4): 227-234, 2014

months. Other studies including Vilchez et al.[32], van Kleunen et al.[34], and Tsukayama et al.[6] have also claimed favorable success rates for treatments implemented within 4 weeks. Therefore, it was suggested that radical debridement be performed within a month from arthroplasty[5,33]. But, it is difficult to determine the actual duration of onset of infection symptoms. Clinical symptoms like pain and elevated inflammatory biomarkers during the recovery period after surgery, making it hard to recognize the infection. Meehan et al.[31] reported a high success rate of 89% in 19 cases of streptococcal infection with all of the cases of prosthetic infection occurred >30 days after implantation of prosthesis. In our study, we were unable to secure specific information regarding the duration of infection; however, the average time taken to implement radical debridement was 31.3 days (18-48 days). We had favorable clinical outcomes regardless of the time of surgery.

It is well-documented that the type of infective pathogen and treatment outcome are closely related[10,38]. Gram positive infections are considered easier to treat. However, novel antibiotics show favorable results for gram negative infections also[6]. Brandt et al.[5] and Azzam et al.[10] reported that PJI due to *Staphylococcus aureus* is associated with treatment failure. However, Odum et al.[30], and Barberán et al.[33] reported that a similar failure rate was found with both types of Staphylococci (*Staphylococcus aureus* and coagulase-negative staphylococci); this is contrary to previous reports of a significantly higher failure rate among MRSA isolates as compared to MSSA isolates.

Zimmerli et al.[7] reported a 100% cure rate (12/12) with ciprofloxacin-rifampin therapy for orthopedic device-related staphylococcal infection in a randomized controlled study and concluded that orthopedic device-related infection due to rifampin and ciprofloxacin susceptible staphylococcal infection can be cured without removal of the device. Meehan et al.[31] reported that only 11% of cases (streptococcal infection after arthroplasty) had failed treatment when patients after radical debridement were treated with intravenous penicillin/ampicillin or ceftriaxone or cefazolin for an average of 4 weeks followed by long-term oral cephalosporins. In our study, we were unable to isolate pathogens in nine patients (45%). The low rate of pathogen isolation could be due to a four-day prophylactic antibiotic regimen post-surgery, which was continued for 7-10 days if the CRP levels were high. We proceeded with early active radical debridement without hesitation if clinical symptoms and blood tests suggested an infection, without performing joint aspiration or other measures for culture.

Although several factors such as age, rheumatoid arthritis and diabetes make patients vulnerable to infection, no study has reported such associations in patients with early infection following hip arthroplasty[9,37]. In our study, most patients had good overall health although a few had unrelated medical disorders (Table 1).

It has been reported that presence of a sinus tract[37], low levels of CRP at the time of infection (15-22 mg/L or lower)[32] and continuous drainage after radical debridement[10] are important factors influencing the clinical outcome. In our study, we found sinus tracts or persistent wound discharge in three patients while the averages of preoperative CRP and ESR were 21.1 mg/L (range 1-72 mg/L) and 49.85 mm/h (range 3-118 mm/h), respectively. No statistically significant association was found between the duration of antibiotic administration and CRP level before radical debridement (P=0.146).

Although there are several antibiotic treatment protocols for early PJI, no specific guideline for duration of antibiotic treatment has been established. Zimmerli et al.[39] recommended 2-4 weeks of intravenous therapy followed by oral antibiotics for 3 months. Vilchez et al.[32], on the other hand, used intravenous administration of antibiotics for 10.6±6.7 days and oral administration was continued for 88±45.9 days. In another study, Choong et al.[9] used vancomycin until pathogen identification before radical debridement and thereafter, relevant antibiotics were administrated for 2 weeks. Oral antibiotics (e.g., rifampin) were given for 4-24 months. Marculescu et al.[37] administered intravenous antibiotics for an average of 28 days and oral antibiotics for an average of 541 days. Barberán et al.[33] used levofloxacin and rifampin after radical debridement for six weeks. We treated our patients with intravenous antibiotics for at least 4-6 weeks after radical debridement or until normal CRP levels were regained. Nine patients who had no microbiological isolate were treated solely with vancomycin while combinations of vancomycin/aminoglycoside were given to three, vancomycin/levofloxacin to two, vancomycin/ertapenem to two and vancomycin/tazocin to one. The average duration of antibiotic administration was 43.5 days (28-62 days) and CRP levels recovered within 8 weeks in most cases. We found that the duration of antibiotics administration was significantly longer in patients with isolated pathogens.

This could be due to the isolated pathogens in our patients being either methicillin-resistant strains or Gram-negative strains, which are more virulent.

We had favorable outcomes with early debridement with prosthesis retention in early PJI. We recommend this procedure not only because of favorable outcomes, but also due to less physical and economic burden on patients and physicians. The isolated pathogens in our study were antibiotic resistant and virulent (e.g., *Enterococcus*) strains. Early radical debridement was implemented as soon as postoperative infective symptoms were noted. Furthermore, hip joint membranes were completely washed during radical debridement and all possible infection sites were packed for 5-10 minutes with gauze soaked in povidone-iodine solution. These could have contributed to our favorable surgical outcomes. However, radical debridement is not recommended for patients who are elderly, have significant medical comorbidities (e.g., advanced diabetes), or are transferred from other hospitals with infection after arthroplasty.

Being a retrospective study there was no control group. However, patients had follow-up for at least one year and we included all patients who met the diagnostic criteria. Certain details such as infective symptoms and duration were lacking, but we tried to verify patients' conditions using available medical records. The sample size of 20 is small, which is a limitation for statistical analysis of treatment outcomes. However, the results herein are significant as they describe the clinical outcome of surgeries performed by the same surgeon using established diagnostic criteria and surgical procedures.

CONCLUSION

We found that a combination of radical debridement with retention of prosthesis and administration of antibiotics could be an effective treatment option for early PJI after hip arthroplasty. The outcome of radical debridement can be significantly improved through careful patient selection, optimal timing of intervention, and thorough debridement. Long-term studies with more number of patients are required to validate our study findings.

REFERENCES

1. Gristina AG, Costerton JW. *Bacterial adherence to biomaterials and tissue. The significance of its role in clinical sepsis. J Bone Joint Surg Am. 1985;67:264-73.*
2. Song Z, Borgwardt L, Høiby N, Wu H, Sørensen TS, Borgwardt A. *Prosthesis infections after orthopedic joint replacement: the possible role of bacterial biofilms. Orthop Rev (Pavia). 2013;5:65-71.*
3. Kaltsas DS. *Infection after total hip arthroplasty. Ann R Coll Surg Engl. 2004;86:267-71.*
4. Fisman DN, Reilly DT, Karchmer AW, Goldie SJ. *Clinical effectiveness and cost-effectiveness of 2 management strategies for infected total hip arthroplasty in the elderly. Clin Infect Dis. 2001;32:419-30.*
5. Brandt CM, Sistrunk WW, Duffy MC, et al. *Staphylococcus aureus prosthetic joint infection treated with debridement and prosthesis retention. Clin Infect Dis. 1997;24:914-9.*
6. Tsukayama DT, Estrada R, Gustilo RB. *Infection after total hip arthroplasty. A study of the treatment of one hundred and six infections. J Bone Joint Surg Am. 1996; 78:512-23.*
7. Zimmerli W, Widmer AF, Blatter M, Frei R, Ochsner PE. *Role of rifampin for treatment of orthopedic implant-related staphylococcal infections: a randomized controlled trial. Foreign-Body Infection (FBI) Study Group. JAMA. 1998;279:1537-41.*
8. Crockarell JR, Hanssen AD, Osmon DR, Morrey BF. *Treatment of infection with débridement and retention of the components following hip arthroplasty. J Bone Joint Surg Am. 1998;80:1306-13.*
9. Choong PF, Dowsey MM, Carr D, Daffy J, Stanley P. *Risk factors associated with acute hip prosthetic joint infections and outcome of treatment with a rifampinbased regimen. Acta Orthop. 2007;78:755-65.*
10. Azzam KA, Seeley M, Ghanem E, Austin MS, Purtill JJ, Parvizi J. *Irrigation and debridement in the management of prosthetic joint infection: traditional indications revisited. J Arthroplasty. 2010;25:1022-7.*
11. Spangehl MJ, Masri BA, O'Connell JX, Duncan CP. *Prospective analysis of preoperative and intraoperative investigations for the diagnosis of infection at the sites of two hundred and two revision total hip arthroplasties. J Bone Joint Surg Am. 1999;81:672-83.*
12. Parvizi J, Ghanem E, Menashe S, Barrack RL, Bauer TW. *Periprosthetic infection: what are the diagnostic challenges? J Bone Joint Surg Am. 2006;88 Suppl 4:138-47.*
13. Yi PH, Cross MB, Moric M, Sporer SM, Berger RA, Della Valle CJ. *The 2013 Frank Stinchfield Award: Diagnosis of infection in the early postoperative period after total hip arthroplasty. Clin Orthop Relat Res. 2014;472:424-9.*
14. Senthi S, Munro JT, Pitto RP. *Infection in total hip replacement: meta-analysis. Int Orthop. 2011;35:253-60.*
15. Coventry MB. *Treatment of infections occurring in total hip surgery. Orthop Clin North Am. 1975;6:991-1003.*
16. Smith PN, Palenik CJ, Blanchard SB. *Microbial contamination and the sterilization/disinfection of surgical guides used in the placement of endosteal implants. Int J Oral Maxillofac Implants. 2011;26:274-81.*
17. Rutala WA, Weber DJ. *Healthcare Infection Control Practices Advisory Committee. Guideline for disinfection*

Hip Pelvis 26(4): 227-234, 2014

and sterilization in healthcare facilities, 2008. Centers for Disease Control and Prevention; 2008. Available from: http://www.cdc.gov/hicpac/Disinfection_Sterilization/acknowledg.html.
18. Oduwole KO1, Glynn AA, Molony DC, et al. *Anti-Biofilm Activity of Sub-Inhibitory Povidone-Iodine Concentrations against Staphylococcus Epidermidis and Staphylococcus Aureus. J Orthop Res. 2010;28:1252-5.*
19. DeLee JG, Charnley J. *Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop Relat Res. 1976;121:20-32.*
20. Sutherland CJ, Wilde AH, Borden LS, Marks KE. *A ten-year follow-up of one hundred consecutive Müller curved-stem total hip-replacement arthroplasties. J Bone Joint Surg Am. 1982;64:970-82.*
21. Engh CA, Massin P, Suthers KE. *Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. Clin Orthop Relat Res. 1990;257: 107-28.*
22. Kawamura H, Dunbar MJ, Murray P, Bourne RB, Rorabeck CH. *The porous coated anatomic total hip replacement. A ten to fourteen-year follow-up study of a cementless total hip arthroplasty. J Bone Joint Surg Am. 2001;83-A:1333-8.*
23. Gruen TA, McNeice GM, Amstutz HC. *"Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res. 1979;141:17-27.*
24. Maloney WJ, Jasty M, Harris WH, Galante JO, Callaghan JJ. *Endosteal erosion in association with stable uncemented femoral components. J Bone Joint Surg Am. 1990;72: 1025-34.*
25. Morrey BF, Westholm F, Schoifet S, Rand JA, Bryan RS. *Long-term results of various treatment options for infected total knee arthroplasty. Clin Orthop Relat Res. 1989;248: 120-8.*
26. Waldman BJ, Hostin E, Mont MA, Hungerford DS. *Infected total knee arthroplasty treated by arthroscopic irrigation and débridement. J Arthroplasty. 2000;15:430-6.*
27. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. *Periprosthetic joint infection: the incidence, timing, and predisposing factors. Clin Orthop Relat Res. 2008;466:1710-5.*
28. Parvizi J, Adeli B, Zmistowski B, Restrepo C, Greenwald AS. *Management of periprosthetic joint infection: the current knowledge: AAOS exhibit selection. J Bone Joint Surg Am. 2012;94:e104.*
29. Koyonos L, Zmistowski B, Della Valle CJ, Parvizi J. *Infection control rate of irrigation and débridement for periprosthetic joint infection. Clin Orthop Relat Res. 2011; 469:3043-8.*
30. Odum SM, Fehring TK, Lombardi AV, et al. *Periprosthetic Infection Consortium. Irrigation and debridement for periprosthetic infections: does the organism matter? J Arthroplasty. 2011;26(6 Suppl):114-8.*
31. Meehan AM, Osmon DR, Duffy MC, Hanssen AD, Keating MR. *Outcome of penicillin-susceptible streptococcal prosthetic joint infection treated with debridement and retention of the prosthesis. Clin Infect Dis. 2003;36:845-9.*
32. Vilchez F, Martínez-Pastor JC, García-Ramiro S, et al. *Outcome and predictors of treatment failure in early post-surgical prosthetic joint infections due to Staphylococcus aureus treated with debridement. Clin Microbiol Infect. 2011;17:439-44.*
33. Barberán J, Aguilar L, Carroquino G, et al. *Conservative treatment of staphylococcal prosthetic joint infections in elderly patients. Am J Med. 2006;119:993.e7-10.*
34. Van Kleunen JP, Knox D, Garino JP, Lee GC. *Irrigation and débridement and prosthesis retention for treating acute periprosthetic infections. Clin Orthop Relat Res. 2010;468:2024-8.*
35. Bassetti M, Vitale F, Melica G, et al. *Linezolid in the treatment of Gram-positive prosthetic joint infections. J Antimicrob Chemother. 2005;55:387-90.*
36. Tattevin P, Crémieux AC, Pottier P, Huten D, Carbon C. *Prosthetic joint infection: when can prosthesis salvage be considered? Clin Infect Dis. 1999;29:292-5.*
37. Marculescu CE, Berbari EF, Hanssen AD, et al. *Outcome of prosthetic joint infections treated with debridement and retention of components. Clin Infect Dis. 2006;42:471-8.*
38. Deirmengian C, Greenbaum J, Stern J, et al. *Open debridement of acute gram-positive infections after total knee arthroplasty. Clin Orthop Relat Res. 2003;416:129-34.*
39. Zimmerli W, Trampuz A, Ochsner PE. *Prosthetic-joint infections. N Engl J Med. 2004;351:1645-54.*