Surgical Treatment For Periprosthetic Joint Infection: A Review

Periprosthetic Joint Infection and surgical treatment

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***Abstract*—Periprosthetic joint infection (PJI) is one of the complicated issues of total joint arthroplasty with frequent hospital visits and long term management. Misdiagnosis of this issue will lead to infections, disability and even impaired life. The successful treatment of the underlying infection while preserving joint function, PJI management must contain effective patient-adapted diagnosis and treatment based on the algorithm and interdisciplinary collaboration. The cornerstone of optimal surgical treatment is a precise debridement with the removal of all devitalized material and foreign bodies that contain mature biofilm (> 4 weeks). There is a need for research and development of new diagnostic methods with more accuracy and simplicity.**

Keywords—Periprosthetic Joint, Periprosthetic Joint Infection, Surgery, Arthroplasty

Introduction

Periprosthetic joint infection (PJI) is among the most challenging complications of total joint arthroplasty. Patients who undergo revision for infection require more hospital visits and longer lengths of stay and incur higher hospital costs compared to revisions for aseptic loosening [1]. PJI occurs in 1% to 2% of primary and in 4% of revision arthroplasties [2-4]. Due to higher life expectancy, lifestyle changes in increasingly elderly populations and more expectations for mobility in older age, the number of implanted prosthetic joints continues to rise [3]. With a steadily increasing number of implantations, the number of PJI cases also rises continuously. Longer prosthesis indwelling time is associated with a higher cumulative risk for hematogenous infections during the entire implant lifetime. The development of modern detection methods for microbial biofilms helps to recognize even chronic infections that would previously have been missed [5].

Management of PJI requires sophisticated treatment strategies, including multiple surgical revisions and long-term antimicrobial treatment. Accurate diagnosis with identification of the infecting micro-organism(s) and its antimicrobial susceptibility is essential for choosing the most appropriate treatment strategy to eradicate the infection. When missed or undertreated, PJI leads to the persistence of infection and multiple surgical revisions causing poor function or disability, considerably impairing quality of life [4]. For the doctor, the treatment and diagnosis of PJI is still tricky. The implant is after al a foreign body that increases the pathogenicity of bacteria, and the appearance of biofilm makes the diagnosis and treatment complex and challenging [6]. Therefore, a suitable management protocol of PJI should be established promptly to take preventive measures and diagnosis to avoid high rates of bacterial resistance and select suitable antibiotics combined with adequate operation procedures. Ultimately, it achieves eradicating infection, preserving joint function without any pain. In this review article, we discuss an outlook on the PJI, including epidemiology, pathogenesis, classification and treatment focusing on the surgical treatment of PJI.

Epidemiology

Arthroplasty is a widespread procedure that is cost-effective, helps the patients get rid of the symptoms, recover functions and enhance the quality of life, especially in the elderly population [3, 7]. With the addendum of the joint prosthetic replacements, it increases the volume of postoperative complications. The infection rate after shoulder or hip replacement is usually less than 1%, while knee replacement is less than 2%, more that elbow replacement which is between 1.9% and 10.3%. The reason for the higher incidence in elbow region, that may be related to the more frequent trauma, rheumatic disorder, or multiple reconstructive procedures compared to hip and knee surgery [4, 8].

PJI also increases the medical costs, which can be as 24 times higher than without PJI [9], the high cost of PJI is generated by prolonged hospitalization, multiple surgeries and prostheses, and medical supplies [10]. *Staphylococcus aureus* and Coagulase-negative *staphylococci* are the most common microorganisms

in hip and knee PJI [11]. Furthermore, there some pathogenic bacteria that depend on different body regions like Propionibacterium acnes after shoulder replacement and gram-negative bacteria after hip arthroplasty [12].

Pathogenesis and Classification

Around two-thirds of PJI cases are caused through intra-operative inoculation of micro-organisms [4]. Depending on microbial virulence, PJI can manifest either early (within the first four weeks after implantation) or with a delay (typically between three months and three years). Early infections manifest with clear local and systemic signs of inflammation and are predominantly caused by high-virulent pathogens (e.g. *Staphylococcus aureus*, *streptococci*, *enterococci*). Delayed infections present with more subtle symptoms such as joint pain and early loosening and are caused by low-virulent organisms (e.g. coagulase-negative staphylococci or Cutibacterium species) [4].

All prosthetic joints remain susceptible to hematogenous seeding from a distant primary focus during their entire indwelling time. High vascularity of periprosthetic tissue exposes the prosthesis to the highest risk of hematogenous infection in the first years after implantation. Typically, patients present with acute onset of clinical symptoms after a painless post-operative period [13]. The risk after bacteremia with *S. aureus* is reported by up to 34% [14]. The search for and the elimination of the primary focus is necessary for preventing infection relapse.

Direct spread of infection ('per continuities') occurs either through direct contact between the prosthesis and the outer world (open periprosthetic fracture) or as a spread from a nearby infectious focus (soft tissue infection, osteomyelitis). Table 1 illustrates the classification of PJI into an acute and chronic infection.

Table 1: Classification of PJI into an acute and chronic infection

Type of PJI	Acute PJI	Chronic PJI
Pathogenesis		
Perioperative origin	Early postoperative	Delayed postoperative (low-grade)
	<4 weeks after surgery	≥4 weeks after surgery
Hematogenous origin	<3 weeks of symptoms	≥3 weeks of symptoms
Biofilm age (maturity)	Immature	Mature
Clinical features	Acute joint pain, fever, red/swollen joint	Chronic pain, loosening of the prosthesis, sinus tract (fistula)
Causative microorganism	High-virulent: *Staphylococcus* aureus, gram-negative bacteria (e.g. *Escherichia* coli, *Klebsiella* spp., *Pseudomonas aeruginosa*)	Low-virulent: Coagulase-negative staphylococci (e.g. *Staphylococcus epidermidis*), *Propionibacterium acnes*
Surgical treatment	Debridement & retention of the prosthesis (change of mobile parts)	Complete removal of the prosthesis (exchange in one-, two-, or multiple stages)

Treatment

The management of PJI includes surgical treatment based on PJI classification as well as recommendations for empirical and targeted antimicrobial therapy for various surgical strategies and causative micro-organisms (Fig. 1) [4, 15].

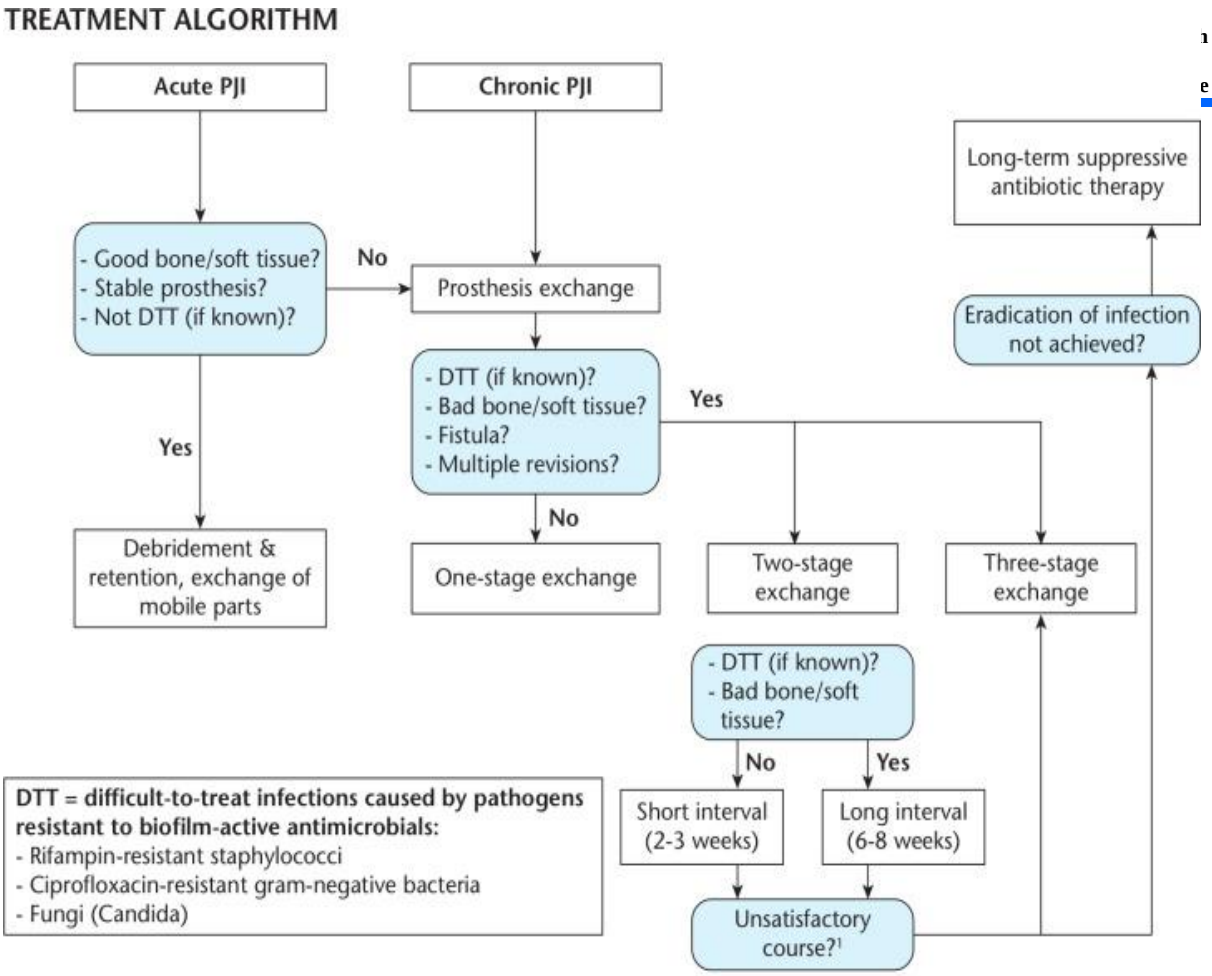

Fig. 1 Treatment algorithm for PJI

Adapted from the Pocket Guide to Diagnosis & Treatment of PJI, PRO-IMPLANT Foundation (version 9) [16]
An appropriate operation combining with an antimicrobial concept is required for successful treatment. However, in this review, we will focus on the surgical part of the treatment.

Surgical Therapy

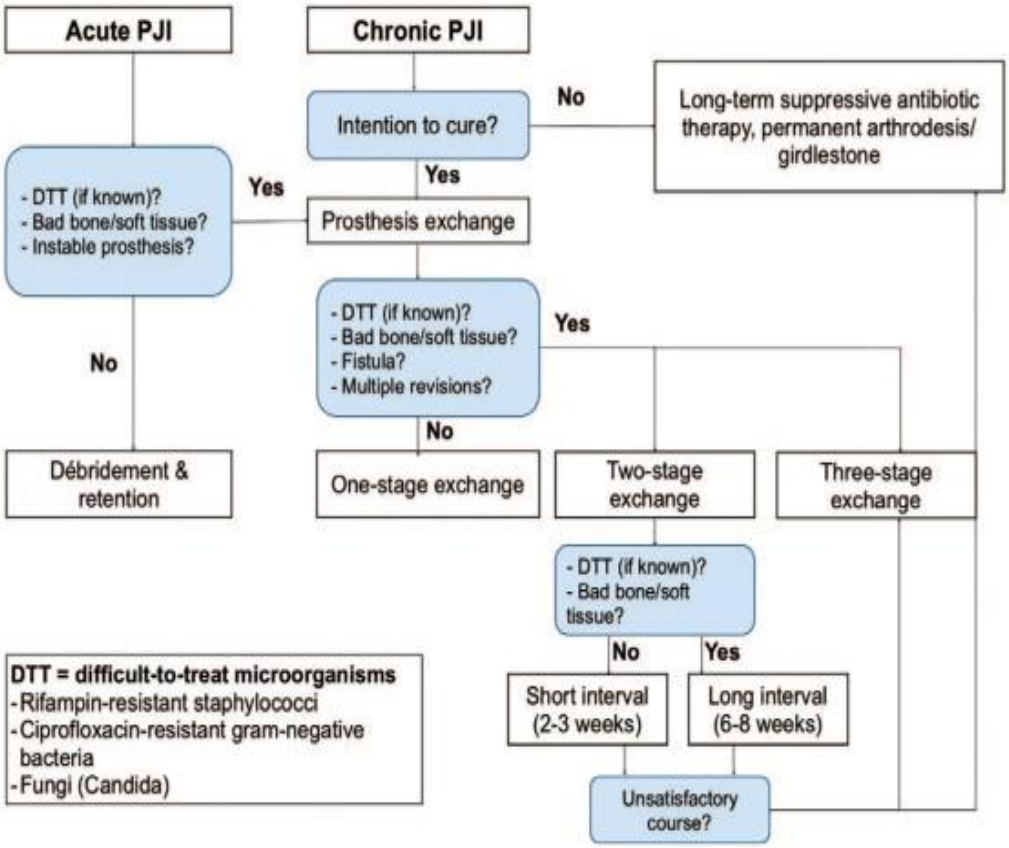

Fig. 2 Surgical treatment of PJI

Primary surgical strategy for the treatment of PJI includes debridement and implant retention, one-stage implant replacement or two-stage implant replacement (Fig. 2).

Debridement with retention

The principles of debridement for infected arthroplasty are to prohibit antibiotics and to aspirate the joint to identify organisms before surgery. The surgical procedure involves removal of skin margins, excision of any sinuses, radical synovectomy and exchange of removable. A suction drain should be left in situ until there is minimal output. If drainage persists or if the infection fails to settle, then consideration must be given to a further debridement procedure. Continuous closed irrigation has not proven to be any more effective than standard procedure with primary closure and in situ drain [17]. Early studies of debridement combining with retention strategies to treat prosthetic joint infection have high failure rates [18], nevertheless, in certain conditions, it can have a success rate higher than 80%, these conditions are [19]: (1) the prosthesis is stable; (2) there is no sinus tract or compromised soft tissue; (3) a pathogen with susceptibility to antimicrobial agents is active against surface-adhering microorganisms; (4) symptom duration of infection is less than three weeks. A recent study of Tschudin-Sutter, 2016) assessing the long-term outcome of treatment for orthopedic device-related infection (ODRI) with retention reported that 90% of orthopedic device-related infections were successfully cured with surgical debridement and implant-retention in addition to long-term antimicrobial therapy according to a predefined treatment algorithm if patients fulfilled strict selection criteria and there was susceptibility to rifampin for Gram-positive pathogens and ciprofloxacin for Gram-negative pathogens [20].

One-stage implant replacement

Single-stage exchange arthroplasty for periprosthetic joint infection goes against traditional dogma, as standard treatment has been based on a staged surgical technique in order to assure infection eradication prior to implantation of a new prosthesis. One-stage exchange is appropriate for patients who have good bone conditions and soft tissue without sinus tract, as well as known bacteria with no difficult-to-treat (DTT) infections caused by pathogens resistant to biofilm-active antimicrobials [19]. The two-staged approach has become the method of choice for most surgeons worldwide, with reported re-infection in between 9% and 20% of cases [21, 22]. Besides the apparent benefit by eliminating a second major operation, further significant advantage arises from the reduced duration of post-operative systemic antibiotics, which rarely prolongs more than 14 days [23]. The rationale for this has also been evaluated in a study by Hoad-Reddick et al., [24] where the authors concluded that a prolonged course of antibiotics does not seem to alter the incidence of

recurrent or persistent infection, even after a two-staged revision. The success rate of one-stage exchange could reach 100%, suggesting that one-stage exchange is a safe procedure, even without local antibiotic treatment, provided that the patient has no sinus tract or severe soft tissue damage, no major bone grafting is required. The microorganism is susceptible to orally administered agents with high bioavailability [25]. In another study, the success rate of one-stage replacement is from 85% to 90% over 35 years [23]. The one-stage implant replacement is an effective surgery with a high success rate, earlier mobility, a shorter period of hospitalization and more cost effective than two-stage exchange.

Two-stage implant replacement

Two-stage revision arthroplasty is the gold-standard treatment for PJI. The first stage involves the removal of all components, cement, and compromised soft tissues with the placement of an antibiotic-impregnated spacer. Spacer options include both mobile and static spacers. Mobile spacers offer maintenance of ambulation and joint range of motion between staged procedures and have shown to be as effective in eradicating infection as static spacers [26]. The process of short interval (2–4 weeks) is convenient for patients who have known and easily treatable organism, compromised soft tissue or sinus tract. The approach of a long interval (8 weeks) is suitable for the organism, which is unknown or DTT and strongly compromised soft tissue [27]. The success rate was reported in 1995 by reviewing 25 studies showing an 82% success rate of two-stage revision compared to 58% with one-stage revision (Garvin & Hanssen, 1995). Numerous studies have reported that two-stage revision with the use of antibiotic spacers can result in infection eradication rates as high as 90:95% [4, 28, 29]. Reinfection must be considered, in one-stage studies, the rate (95% confidence intervals) of re-infection was 8.2% (6.0–10.8). The corresponding re-infection rate after the two-stage revision was 7.9% (6.2–9.7). Re-infection rates remained generally similar when grouped by several studies and population-level characteristics [30]. In case there are more than three morbidities and a high ESR or CRP before reimplantation, the risk of reinfection is high [31].

Antimicrobial Therapy

Antimicrobial therapy is recommended for 12 weeks after the surgical procedure. Starting empirical, broad-spectrum antimicrobial treatment only after the reduction of bacterial load by surgical debridement and the initial intravenous application improve the treatment effectivity and reduce the development of antimicrobial resistance. De-escalation to targeted therapy should follow as soon as the causative agent is identified. Switch to oral treatment may be performed 14 days after surgery if an oral substance with good bone penetration is available, wounds are dry, local conditions satisfactory, and systemic inflammatory markers (e.g. CRP) have returned to normal or almost normal values. For streptococci, potentially longer intravenous therapy is necessary (typically three to four weeks), as oral amoxicillin may not reach sufficient tissue concentrations.

References

1. Bozic, Kevin J, and Michael D Ries. “The impact of infection after total hip arthroplasty on hospital and surgeon resource utilization.” *The Journal of bone and joint surgery. American volume* vol. 87,8 (2005): 1746-51. doi:10.2106/JBJS.D.02937
2. Corvec, Stéphane et al. “Epidemiology and new developments in the diagnosis of prosthetic joint infection.” The International journal of artificial organs vol. 35,10 (2012): 923-34. doi:10.5301/ijao.5000168
3. Kurtz, Steven et al. “Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030.” The Journal of bone and joint surgery. American volume vol. 89,4 (2007): 780-5. doi:10.2106/JBJS.F.00222
4. Zimmerli, Werner et al. “Prosthetic-joint infections.” The New England journal of medicine vol. 351,16 (2004): 1645-54. doi:10.1056/NEJMra040181
5. Karczewski, D et al. “A standardized interdisciplinary algorithm for the treatment of prosthetic joint infections.” The bone & joint journal vol. 101-B,2 (2019): 132-139. doi:10.1302/0301-620X.101B2.BJJ-2018-1056.R1
6. Ong, Kevin L et al. “Prosthetic joint infection risk after total hip arthroplasty in the Medicare population.” The Journal of arthroplasty vol. 24,6 Suppl (2009): 105-9. doi:10.1016/j.arth.2009.04.027
7. Oleske, Denise M et al. “Electronic health databases for epidemiological research on joint replacements: considerations when making cross-national comparisons.” Annals of epidemiology vol. 24,9 (2014): 660-5. doi:10.1016/j.annepidem.2014.06.003
8. Achermann, Y et al. “Characteristics and outcome of 27 elbow periprosthetic joint infections: results from a 14-year cohort study of 358 elbow prostheses.” Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases vol. 17,3 (2011): 432-8. doi:10.1111/j.1469-0691.2010.03243.x
9. Alp, Emine et al. “Incidence and economic burden of prosthetic joint infections in a university hospital: A report from a middle-income country.” Journal of infection and public health vol. 9,4 (2016): 494-8. doi:10.1016/j.jiph.2015.12.014
10. Haenle, M, Skripitz, C, Mittelmeier, W, & Skripitz, R. “Economic impact of infected total knee arthroplasty.” The Scientific World Journal, 2012(2012). https://doi.org/10.1100/2012/196515
11. Aggarwal, Vinay K et al. “Organism profile in periprosthetic joint infection: pathogens differ at two arthroplasty infection referral centers in Europe and

in the United States." The journal of knee surgery vol. 27,5 (2014): 399-406. doi:10.1055/s-0033-1364102
12. Piper, KE et al. "Microbiologic diagnosis of prosthetic shoulder infection by use of implant sonication." Journal of Clinical Microbiology, vol. 47(6), (2009): 1878–1884. https://doi.org/10.1128/JCM.01686-08
13. Rakow, A et al. "Origin and characteristics of haematogenous periprosthetic joint infection." Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases vol. 25,7 (2019): 845-850. doi:10.1016/j.cmi.2018.10.010
14. Murdoch, D R et al. "Infection of orthopedic prostheses after Staphylococcus aureus bacteremia." Clinical infectious diseases : an official publication of the Infectious Diseases Society of America vol. 32,4 (2001): 647-9. doi:10.1086/318704
15. Trampuz A, Zimmerli W. New strategies for the treatment of infections associated with prosthetic joints. Curr Opin Investig Drugs. 2005 Feb;6(2):185-90. PMID: 15751742.
16. Izakovicova, Petra et al. "Periprosthetic joint infection: current concepts and outlook." EFORT open reviews vol. 4,7 482-494. 29 Jul. 2019, doi:10.1302/2058-5241.4.180092
17. Royo, Antonio et al. "Is there still a place for continuous closed irrigation in the management of periprosthetic total knee infection?." The open orthopaedics journal vol. 7 205-10. 14 Jun. 2013, doi:10.2174/1874325001307010205
18. Deirmengian, Carl et al. "Limited success with open debridement and retention of components in the treatment of acute Staphylococcus aureus infections after total knee arthroplasty." The Journal of arthroplasty vol. 18,7 Suppl 1 (2003): 22-6. doi:10.1016/s0883-5403(03)00288-2
19. Trampuz, Andrej, and Werner Zimmerli. "Prosthetic joint infections: update in diagnosis and treatment." Swiss medical weekly vol. 135,17-18 (2005): 243-51.
20. Tschudin-Sutter, S et al. "Validation of a treatment algorithm for orthopaedic implant-related infections with device-retention-results from a prospective observational cohort study." Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases vol. 22,5 (2016): 457.e1-9. doi:10.1016/j.cmi.2016.01.004
21. Azzam, Khalid et al. "Outcome of a second two-stage reimplantation for periprosthetic knee infection." Clinical orthopaedics and related research vol. 467,7 (2009): 1706-14. doi:10.1007/s11999-009-0739-4
22. Haleem AA, Berry DJ, Hanssen AD. "Mid-term to long-term followup of two-stage reimplantation for infected total knee arthroplasty." Clinical orthopaedics and related research. 428, 2004:35-39. https://doi.org/10.1097/01.blo.0000147713.6423 5.73
23. Kendoff, D, & Gehrke, T. "One stage exchange arthroplasty : the devil is in the detail." Journal of Bone & Joint Surgery, 1–6, 2012.
24. Hoad-Reddick, D A et al. "Is there a role for extended antibiotic therapy in a two-stage revision of the infected knee arthroplasty?." The Journal of bone and joint surgery. British volume vol. 87,2 (2005): 171-4. doi:10.1302/0301-620x.87b2.15640
25. Ilchmann, T, Zimmerli, W, Ochsner, PE. et al. "One-stage revision of infected hip arthroplasty: outcome of 39 consecutive hips". International Orthopaedics (SICOT) 40, 913–918 (2016). https://doi.org/10.1007/s00264-015-2833-4
26. Osmon, Douglas R et al. "Diagnosis and management of prosthetic joint infection: clinical practice guidelines by the Infectious Diseases Society of America." Clinical infectious diseases : an official publication of the Infectious Diseases Society of America vol. 56,1 (2013): e1-e25. doi:10.1093/cid/cis803
27. Charette, Ryan S, and Christopher M Melnic. "Two-Stage Revision Arthroplasty for the Treatment of Prosthetic Joint Infection." Current reviews in musculoskeletal medicine vol. 11,3 (2018): 332-340. doi:10.1007/s12178-018-9495-y
28. Garvin, K L, and A D Hanssen. "Infection after total hip arthroplasty. Past, present, and future." The Journal of bone and joint surgery. American volume vol. 77,10 (1995): 1576-88. doi:10.2106/00004623-199510000-00015
29. de Carvalho Júnior, LH, Temponi, EF, & Badet, R. "Infection after total knee replacement: diagnosis and treatment. (2013). Revista Brasileira de Ortopedia (English Edition), 48(5), (2013):389–396. https://doi.org/10.1016/j.rboe.2013.01.003
30. Kunutsor, Setor K et al. "Re-Infection Outcomes following One- and Two-Stage Surgical Revision of Infected Hip Prosthesis: A Systematic Review and Meta-Analysis." PloS one vol. 10,9 e0139166. 25 Sep. 2015, doi:10.1371/journal.pone.0139166
31. Cha, Min Seok et al. "Two-Stage Total Knee Arthroplasty for Prosthetic Joint Infection." Knee surgery & related research vol. 27,2 (2015): 82-9. doi:10.5792/ksrr.2015.27.2.82