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Operative Techniques in
Orthopaedics

One-Stage Exchange Revision Arthroplasty for the Treatment of Prosthetic Joint Infection: Rational and Technique

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Prosthetic joint infection is devastating complication of total joint arthroplasty and represents a significant burden both financially and to the patient's overall health. Challenges are in part due to difficulty in eradicating the disease and that there is no census in the most economical and effective techniques for treatment. In the United States the treatment standard is a 2-stage exchange in which the components are removed and an antibiotic spacer is placed, several weeks of intravenous antibiotics, and then a second procedure to remove the antibiotic spacer and place the final components. A 1-stage exchange removes the infected components and places new components in the same surgical setting. The success rate are similar between the 2 options but to date no large scale randomized study has been performed, however a 1-stage exchange limits the total number operations, decreases the morbidity associated in between stages, and is associated with a decrease in overall cost. Surgeons treating prosthetic joint infections should consider this technique.
Oper Tech Orthop 29:100731

KEYWORDS prosthetic joint infection, arthroplasty, 1-stage exchange, 2-stage exchange

Introduction

Total joint arthroplasty (TJA) is a very successful procedure with the total number of patients expected to continue to increase in the coming years. Prosthetic joint infection (PJI) following TJA is a devastating complication with substantial morbidity and a decline in functional outcomes. Fortunately the risk of infection following arthroplasty is low, around 1%-3% after primary total knee arthroplasty and 1%-2% after primary total hip arthroplasty (THA).[1,2] PJI is the number 1 cause of failure of total knee arthroplasty and third most common cause of failure of THA.[3,4] Patients with PJI have a mortality rate of 25.9% at 5 years, which is 4-fold higher than the mortality of age and comorbidity matched groups of patients undergoing revision arthroplasty for noninfected cause.[11] The 5-year survivorship of patients with PJI is less than those treated for breast cancer, melanoma, Hodgkin's lymphoma, and testicular cancer.[11] The treatment of PJI is also costly. The annual economic impact of PJI in the US is projected to exceed 1.62 billion by 2020.[5]

The treatment of PJI is significant challenge facing the orthopaedic community. One of the major problems associated with PJI is the formation of a complex glycocalyx structure called a biofilm. This protective film is produced by the infecting organisms after the bacteria adheres to the implants surface. The biofilm allows the bacteria to escape the host's immune system and is impenetrable to antibiotics. Currently in the United States 2-stage exchange is considered the gold standard for deep PJI (Fig. 1). During a 2-stage exchange arthroplasty, the implants are removed, infected tissues are debrided and a temporary antibiotic impregnated spacer fashioned from polymethylmethacrylate is placed (stage 1). Afterwards the patient undergoes approximately 6 weeks of intravenous antibiotics, followed by reimplantation at a later date (stage 2). During the time between stages patients often

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https://doi.org/10.1016/j.oto.2019.100731

Figure 1 A patient with a draining sinus tract, who had a history of skin breakdown requiring split thickness skin graft.

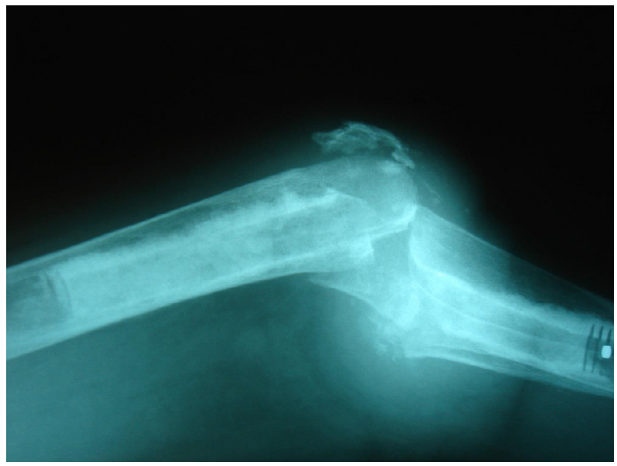

Figure 2 A lateral radiograph of a patient who underwent an explant of an infected knee prosthesis with static antibiotic spacer that has fractured and flexed.

experience pain and immobility compared to baseline, and are at risk for systemic toxicity associated with the administration of antibiotics.[6]

One alternative for the treatment of PJI is a 1-stage exchange arthroplasty. As the name implies, this procedure involves the removal of the infected prosthesis, debridement of infected tissues, and a new prosthesis is reimplanted during the same operative procedure (Fig. 1). One-stage exchange arthroplasty is the preferred method of treatment for chronic PJI in some centers in Europe, which have reported comparable results to that of 2-stage exchange arthroplasty.[7-10] The potential benefits of a 1-stage arthroplasty are numerous and include: reduced morbidity as only 1 surgery needs to be performed, reduced hospitalizations, reduced cost, and most importantly a reduced period of disability for the patient.[9,10] Additionally a 1-stage alternative avoids issues that arise with antibiotic-impregnated cement spacers such as pain, systemic toxicity from high dose antibiotics, mechanical complications related to the spacer such as fractures, dislocation, etc[12-14] (See Fig. 2). Finally, there is an 11% risk of mortality between stages with a 2-stage protocol.[15] A 1-stage protocol may have the potential to improve this statistic.

Despite the many potential advantages of a 1-stage exchange arthroplasty, its acceptance has been slow in the United States. Part of the unwillingness to use a 1-stage protocol may be financial as the surgery itself on average takes 2-3 times longer than a primary joint and the reimbursement rate is only about 10% higher than that of a primary joint.[16]

To date no large randomized controlled trial has been performed to compare the outcomes of the single and 2-stage exchanges. Research at our institution and several others as part of a multicenter randomized controlled trial is currently underway to determine if 1-stage exchange arthroplasty for PJI is an effective and safe method when compared directly to 2-stage exchange. While early results are promising it is outside the scope of this article to publish any results.

Diagnosis and Criteria for 1-Stage Exchange Arthroplasty

The diagnosis of PJI has been discussed elsewhere and continues to be point of debate. We currently rely on the many of the tenants laid out by the Musculoskeletal Society Infection Society definition of PJI from 2011[17](Table 1). Additionally a prosthetic joint is considered infected if 1 of 2 major criteria exist, a sinus tract communicating with the prosthesis (see Fig. 1) or a pathogen isolated by culture from at least 2 separate tissue or fluid samples obtained from the affected joint. Alternatively an artificial joint is considered infected if 3 of the following 5 criteria exist: an elevated serum erythrocyte sedimentation rate above

Table 1 AORI Bone Defect Types

Type 1 defect
• Intact metaphyseal bone
• Good cancellous bone at or near a normal joint-line level
Type 2 defect
• Damaged metaphyseal bone
• Loss of cancellous bone that requires cement fill, augments, or small bone grafts to restore a reasonable joint-line level
• 2A-one femoral or tibial condyle
• 2B-both femoral or tibial condyles
Type 3 defect
• (Deficient metaphyseal bone)

30 mm/h, a serum C-reactive protein concentration above 10 mg/L, elevated leukocyte count above 3000 cells/μL, elevated synovial neutrophil percentage (PMN%) above 80%, isolation of microorganism in 1 culture of periprosthetic tissue or fluid, or greater than 5 neutrophils per high-power fields observed from histologic analysis of periprosthetic tissue at ×400 magnification.

There are several new available commercial products available for the detection of PJI. We use synovial alpha-defensin as confirmatory test rather than a screening test. Recent studies indicate that lateral flow point of contact test for alpha-defensin showed a sensitivity of 54%-84% depending on the criteria defined by 3 different infection organizations.[17] Molecular diagnosis of PJI is of recent research interest. Next generation sequencing is used to identify pathogens in synovial fluid and tissue and shows promise in identifying a pathogen in 89% of infected cases.[18] Currently there are limitations to the use of next generation sequencing in our practice as microbes have been isolated in 25% of aseptic revision with negative cultures and 35.3% or primary joint arthroplasties. Sonication is a diagnostic technique in which the retrieved implant in subjected to ultrasonic waves and the biofilm is theoretically broken up and allows the bacteria to grow in culture. Currently this is not available at our institute, but this also hold promise in identifying pathogens in suspected infection cases.[19] While many of these new diagnostic technologies show promise currently we are using them judiciously and as confirmatory tests.

Currently most patients with a chronic PJI are eligible for 1-stage treatment. Our only exclusions criteria that would prevent patients from being considered for a 1-stage exchange are: patients with systemic sepsis who require emergent surgery, patients with extensive soft tissue involvement that would prevent the closure of the wound after reimplantation, fungal infections, HIV positive patients, or patients on chemotherapy. All other patients with symptoms lasting greater than 4 weeks are considered for a 1-stage exchange.

Technique

For patients who had an isolated sensitive organism identified preoperatively receive appropriate antibiotics within 1 hour of skin incision. Tranexamic acid is give in some form (intravenous, orally, or topically) in all patients without a contraindications. In our practice we typically use 1 g of tranexamic acid intravenous at incision. If synovial fluid cultures have not grown an organism antibiotics are held until intraoperative cultures are taken. Prior to entering the joint we attempt to aspirate any fluid for culture, if we are unable to obtain any through aspiration we enter the joint and then attempt to take at least 2 fluid samples. Synovial tissue cultures are then taken from different areas of the joint. The existing implants are removed. For knee patients bone cultures are taken from the femoral and tibial canal. For hip patients, bone cultures are obtained from the acetabulum and the femur. If no fluid was obtained on entering the joint an additional tissue culture is sent.

A radical debridement of all foreign tissue and synovium is performed, including debriding the inner surface of the entire capsule. This includes the posterior capsule of knee which is debrided with care. Bony surfaces are also debrided, through gentle reaming of the femur and acetabulum in hips and the femur and tibial canals in knees. Additionally, we do a provisional buffing up each of the knee cuts to remove a few millimeters of infected bone. Pathology specimens are taken from at least 3 areas of the joint at the time of resection. Bone defects for the knee are classified using the AORI Classification System (Table 1). The Paprosky Classification of Acetabular Bone Loss and Femoral Bone Loss (Table 2) is used to classify bone defects of the hip to ensure that we have appropriate implants for the 1-stage exchange arthroplasty.

Once bone defects have been documented, the bone is the prepped for 1-stage implantation by reaming the acetabulum and femur on hips and making new bony cuts with knees. Trials are utilized to assess stability and plan for immediate reimplantation. After we are satisfied with our trials we remove the trial and utilize a 3-step irrigation protocol for all infection surgeries: in step 1 we use a pulse lavage with 3 L of normal saline (NS) followed by lavage with 100 cc's of 3% H_2O_2 in 100 cc's of sterile water, a 50/50 solution is left in the wound for 2 minutes, in step 2 we lavage another 3 L NS followed by 1 L of dilute, sterile Betadine (22.5 mL Betadine/L NS) which is left in wound for 3 minutes. The final step includes another pulse lavage with 3 L of NS. An intramedullary water pic is used to irrigate the canals in addition to a short nozzle for surface irrigation.

A dilute sterile Betadine soaked lap sponge is left in wound while preparing for the 1-stage exchange of new implants. The wound is whip stitched and a Betadine impregnated incisional drape is draped over the wound. In knees the tourniquet is maintained during the transition period. The room is cleaned of any obvious contamination. The operative leg is reprepped, redraped and new instruments are used to replant new implants. In addition the surgical team regowns and regloves.

Reimplantation fixation choice is at the surgeon's discretion. If bone cement is used for fixation, 2 g of organism specific antibiotics is used per 40 g pack of bone cement.

Table 2 Paprosky Classification of Acetabular Bone Loss.

Type I	**Minimal deformity, intact rim**
Type IIA	**Superior bone lysis with intact superior rim**
Type IIB	**Absent superior rim, superolateral migration**
Type IIIC	**Localized destruction of medial wall**
Type IIIA	**Bone loss from 10 am-2 pm around rim, superolateral cup migration**
Paprosky classification of femoral bone loss	
Type I	**Minimal metaphyseal bone loss**
Type II	**Extensive metaphyseal bone loss with intact diaphysis**
Type IIIa	**Extensive metadiaphyseal bone loss, minimum of 4 cm of intact cortical bone in the diaphysis**
Type IIIb	**Extensive metadiaphyseal bone loss, less than 4 cm of intact cortical bone in the diaphysis**
Type IV	**Extensive metadiaphyseal bone loss and a nonsupportive diaphysis**

After reimplantation 1 g of powdered vancomycin is distributed throughout the wound if the patient is not allergic. For knees we release the tourniquet prior to closure and polydioxanone/monofilament suture is used for wound closure.

Postoperative organism specific antibiotics are prescribed by our institute's infectious disease consultant. A total of 6 weeks intravenous antibiotics and 6 months oral antibiotics are prescribed for all patients undergoing a 1-stage exchange. The use of blood management drains, thromboembolic prophylaxis, and weight bearing status are all at the surgeon's discretion.

Conclusion

PJI is difficulty problem to treat with morbidity and mortality meeting or exceeding that of many common forms of cancer. The treatment of PJI with a 1-stage exchange offers potential benefits to patients and payors. While no perfect solution for the eradication of PJI exists 1-stage exchange may be a cost effective solution with diminished patient morbidity. Forthcoming multicenter studies comparing one stage vs 2-stage treatment should clarify the indications and results.

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