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Original Research

Two-Stage Primary Arthroplasty of Native Hips and Knees That Had Previously Failed Treatment for Septic Arthritis: A Single-Center Experience

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ABSTRACT

Background: Patients with a history of degenerative joint disease secondary to an acute or remote episode of septic arthritis of the native knee or hip present a unique challenge for the orthopaedic surgeon. This study describes our experience with two-stage primary arthroplasty for such patients.

Methods: We reviewed 42 patients with a history of septic arthritis treated with two-stage primary arthroplasty between 2008 and 2018. Patients were evaluated using modified Harris Hip Score, Knee Society Score (KSS), and KSS functional component (KSSF). Paired t-tests were used to compare changes for continuous variables within cohorts. Multivariate linear and logistic regression models were constructed to determine predictors of outcomes and complications.

Results: At a mean of 3.3-year follow-up, there were 14 (33.3%) complications and the infection cure rate was 95.2%. On average, patients improved in the modified Harris Hip Score (42.9 ± 11.8 vs 83.3 ± 11.1, $P < .001$), KSS (35.9 ± 16.9 vs 80.1 ± 16.6, $P < .001$), KSSF (38.0 ± 15.1 vs 71.5 ± 24.0, $P < .001$), knee flexion (90.9 ± 14.9 vs 100.5 ± 17.1), and hip flexion (73.8 ± 21.2 vs 102.1 ± 11.8, $P < .001$). Age (β: −0.78, $P = .004$) was independently associated with lower Harris Hip Score in the hip cohort. There were no independent predictors of the KSS or KSSF. The erythrocyte sedimentation rate (odds ratio: 1.07, $P = .043$) and C-reactive protein (odds ratio: 1.43, $P = .018$) at stage 2 were independently associated with a higher likelihood of complications at the final follow-up.

Conclusion: Patients with a history of native septic arthritis of the hip and knee, and secondary end-stage degenerative joint disease, showed significant postoperative improvements and a high rate of complications after two-stage primary total joint arthroplasty. Despite improvements, some patients may necessitate a third operation because of the incidence of reinfection and spacer exchange. This information should be used to counsel patients who present with this challenging clinical scenario.

Introduction

Septic arthritis of the hip and knee continues to present a challenge in orthopaedics with a rapidly increasing prevalence in the United States [1]. This condition can lead to irreversible damage to the affected native joint [2,3]. Septic arthritis can manifest within many different contexts: patients with pre-existing degenerative joint disease who develop septic arthritis, patients who experience recurrent infections despite conventional management, and patients who develop osteoarthritis after septic arthritis. The multifactorial pattern of presentation makes septic arthritis and its sequelae of secondary end-stage degenerative joint disease a clinically challenging scenario to diagnose and treat.

Conventional treatment of native joint infections typically involves intravenous antibiotics and removal of purulent tissue from the affected joint either by arthrocentesis or surgical (open or arthroscopic) drainage [4,5]. The use of primary total joint arthroplasty to treat ongoing/active septic arthritis is a relative contraindication, and these patients are considered poor candidates for

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this procedure [6]. However, in the setting of a treated postseptic arthritis joint that has developed degenerative joint disease, there is a paucity of literature describing treatment, and management with an arthroplasty remains controversial because of the high rates of potential periprosthetic infection [7-9]. Despite this, primary total joint arthroplasty can be used to manage such cases when the infection has been adequately treated and is often taken in 2 stages to complete. Indeed, Diwanji et al. [10] were the first to describe this concept using resection hip arthroplasty and antibiotic spacer placement, and since then, the two-stage exchange procedure has become a common treatment for prosthetic joint infections [11-13]. There is limited literature using this approach in the native hip or knee with a history of previously treated infection or to a hip or knee with active infection when degenerative changes are present [14,15].

The primary aims of this study were to (1) describe the results of two-stage primary arthroplasty from a single institution to treat severe degenerative joint disease secondary to active or treated septic arthritis in the native hip and knee joints and (2) to identify predictors of outcome. It was hypothesized that the two-stage cohort would experience significant improvements in the postoperative period despite the anticipation of a higher risk for complications and that various preoperative variables would be predictive of outcomes in this specific cohort.

Material and methods

Patient selection

After institutional review board approval, all patients who presented to our institution with an acute or remote history of native knee or hip infection that was treated with a two-stage primary arthroplasty between December 2008 and December 2018 by 3 fellowship-trained surgeons in adult reconstruction were identified. Inclusion criteria included a minimum of 2-year follow-up and completion of the entire two-stage exchange protocol. Exclusion criteria included patients who underwent a planned one-stage exchange arthroplasty and those who underwent primary arthroplasty for any other etiology. The diagnosis of a septic joint was based on a history of a remote or acute pyogenic arthritis of the affected joint. All patients in the present study had their secondary arthritis treated conservatively and subsequently presented to our institution—therefore, patients had severe degenerative joint disease and osseous destruction secondary to previously treated postseptic arthritis and presented with either an active infection or chronic changes secondary to a previous infection. For patients classified as having an acute or remote infection, these patients had been previously treated with antibiotics and/or had an arthroscopic or open irrigation and debridement within the same month as the first stage of their arthroplasty. For patients classified as having a chronic/quiescent infection, these patients also had previous treatment with antibiotics and/or irrigation and debridement or had prior nonarthroplasty hardware and history of infection, greater than 1 month before stage 1.

Surgical technique

For native joint infections of the knee, a standard medial parapatellar approach was used. A thorough debridement of all infected tissue was performed including a complete synovectomy. Standard cuts were made as though performing a primary arthroplasty, with the exception of the patella for which the cartilage was denuded, but a definitive cut was not made. An articulating spacer was used in 27 knees, and a static spacer was used in 3 knees. Articulating spacers were made with 1 of 3 cements, based on availability and surgeon preference: Cobalt G-HV with 500 mg gentamicin (Biomet, Warsaw, IN); Palacos G with 500 mg gentamicin (Heraeus, Hanau, Germany); Simplex P with 1 g tobramycin (Stryker, Kalamazoo, MI). Each 40 g dose of polymethylmethacrylate cement was mixed with an additional 3 g of vancomycin and 1.2 g of tobramycin. Reimplantation at stage 2 was performed with the NexGen Legacy Constrained Condylar Knee (LCCK, Zimmer Biomet, Warsaw, IN) system, with femoral and tibial stems used in all patients with concern for insufficient bone stock (n = 27). In the remaining patients, prosthesis selection was based on surgeon preference (NexGen LPS [Zimmer Biomet, Warsaw, IN] with a cemented, short tibial stem [n = 1] and without a tibial stem [n = 2]). The only definitive recut made at the time of final component implantation consisted of patella resurfacing, which was performed in all patients.

Static spacers were made with Palacos (Heraeus, Hanau, Germany) cement. Each dose of Palacos (Heraeus, Hanau, Germany) with 500 mg of gentamicin was mixed with 3 g of vancomycin and 1.2 g of tobramycin. Dowels of antibiotic-loaded cement were used in cases based on the preference of the attending surgeon. Patients were allowed partial weight-bearing. Patients who received articulating spacers were allowed range of motion (ROM) of full extension to 90 degrees of flexion, as tolerated. Patients with a static spacer were placed in a hinged brace locked in full extension. Decision for placement of a static vs articulating spacer was made intraoperatively by the treating surgeon based on the severity of degenerative changes and concern for bone loss.

For native joint infections of the hip, a standard posterior approach was used. An articulating spacer was used in all 12 hips. Similarly, infected tissue was debrided in all cases while ensuring preservation of the abductor musculature. Femoral neck cuts were made to the pretemplated neck length, and antibiotic-coated articulating spacers were used in each case. The acetabulum was sequentially reamed to remove the remaining cartilage, and an antibiotic-loaded femoral head 2 mm smaller than the final reamer was fabricated. Routine femoral preparation of reaming and broaching was performed, so as to achieve a moderate frictional fit. Spacer molds one size smaller than the reamed size were used. Both prefabricated molds and custom molds using rush rods and bulb suction were used based on surgeon preference. Custom molds used 2 cements, again based on surgeon preference and hospital formulary: Palacos G (Heraeus, Hanau, Germany) with 500 mg of gentamicin (Biomet; Warsaw, IN) and Cobalt G-HV with 500 mg of gentamicin (Biomet, Warsaw, IN). One case used a Biomet Prostalac prosthesis (Warsaw, IN) with cement antibiotic beads placed in the anterior and posterior gutters. One other case used Palacos beads (Heraeus, Hanau, Germany) mixed with vancomycin into the acetabulum.

For both native joint infections of the hip and knee, organism-specific IV antibiotics (based on current culture results or historical data if cultures were negative at the time of spacer placement) were administered for 6 weeks in conjunction with an infectious disease specialist. At the end of antibiotic administration, the infected joint was aspirated and cultured. A negative culture on aspiration and decreasing levels of serological markers (erythrocyte sedimentation rate [ESR] and C-reactive protein [CRP]) were used to confirm treatment efficacy. Frozen sections and intraoperative cultures were obtained. For frozen sections, the standard cutoff was >10 white blood cell (WBC)/hfp or >5 WBC/hfp in the setting of elevated ESR/CRP and synovial fluid WBC. Three cultures were also sent in each case: one from the fluid aspiration and 2 from the capsule and either the femoral or tibial canal for the knees or the femoral canal or acetabulum for the hips. Patients were then implanted with the final prosthesis as long as intraoperative findings (degree of degenerative changes, bone quality, and integrity of

soft tissue and supporting ligaments) were in concordance with the preoperative findings.

Functional outcome evaluation and chart review

All patients completed joint-specific outcome instruments preoperatively and at a minimum of 2 years postoperatively, which included the modified Harris Hip Score (mHHS), Knee Society Score (KSS), and KSS functional component (KSSF).

Demographic data consisted of age, sex, body mass index, and Charlson Comorbidity Index at the time of the two-stage exchange procedure. Infectious data consisted of the ESR, CRP, and synovial fluid leukocyte count at the time of the first and second stages of the procedures. Also included in this category was the duration of antibiotic use after stage 1 and the time between diagnosis of infection and stage 1, as well as the time between stage 1 and stage 2. Complications were recorded and defined as either medical or orthopaedic.

Statistical analysis

All statistical tests were performed using Stata, version 15.1 (StataCorp, College Station, TX), and statistical significance was set at $P < .05$. Descriptive statistics were used to quantify the demographic and operative data, with continuous variables reported as means with standard deviations and binary data reported as relative frequencies with percentages. Paired *t*-tests were conducted to determine differences between preoperative and postoperative hip and knee outcome scores. A series of multivariate linear and logistic regression analyses were constructed to determine the influence of demographic and infectious data on postoperative outcomes and the complication rate.

Results

Patient demographics

A total of 42 native joints were treated for acute/active (n = 18, diagnosed and treated within the same month) and chronic/quiescent (n = 24) septic arthritis including both the hips and knees. The mean age was 58.3 ± 15.1 years and body mass index 30.9 ± 5.8 kg/m^2. The mean follow-up was 3.3 ± 1.7 (range, 2.0-10.1) years. The majority (n = 26, 61.9%) of patients were male, and the mean Charlson Comorbidity Index score was 2.6 ± 2.2. A total of 12 patients had septic arthritis of the hip, whereas a total of 30 patients had septic arthritis of the knee. Demographics stratified by involvement of the hip and knee are described in Table 1.

All chronic/quiescent cases underwent previous, non-arthroplasty treatment and did not show signs of infection at the time of spacer implantation. Time from infection to two-stage arthroplasty ranged from 3 months to 20 years. Previous treatments included intravenous antibiotics only (n = 2), prior open irrigation and debridement followed by intravenous antibiotic therapy (n = 12), open irrigation and debridement followed by greater than one intravenous antibiotic therapy treatment (n = 3), tibial plateau open reduction and internal fixation complicated by infection and requiring irrigation and debridement (n = 2), history of osteomyelitis of the operative joint (n = 2), hip fusion resulting in nonunion with hardware placement and chronic infection (n = 1), and prior hip arthroscopy complicated by persistent infection necessitating long-term antibiotic suppression (n = 2). One patient who underwent hip arthroscopy failed arthroscopic irrigation and debridement and later an open synovectomy, irrigation and debridement, ultimately requiring long-term antibiotic suppression. The second patient who underwent hip arthroscopy also underwent open synovectomy, irrigation and debridement but ultimately required long-term antibiotic suppression.

Infection data

Organisms were identified by joint aspiration performed before stage 1 surgery, by cultures grown from intraoperative tissue or by referencing past charts for patients who presented with arthritis years after their osteomyelitis episodes. The most commonly identified infecting organism was coagulase-negative *Staphylococcus aureus* (Table 2). At the latest follow-up, the infection cure rate was 95.2%.

Five (11.9%) patients (1 hip, 4 knees) required a second spacer for evidence of persistent infection before the final prosthetic implantation. Three patients presented with acute infections, whereas 2 presented with chronic infections. One patient in the hip cohort failed stage 1 and required reimplantation with a second antibiotic spacer. Similarly, a total of 4 patients in the knee cohort required reimplantation with an antibiotic spacer after stage 1. Three of these patients had negative cultures (stage 1: methicillin-resistant *Staphylococcus aureus*, stage 2: no culture; stage 1: coagulase-negative *S. aureus*, stage 2: no culture; stage 1: coagulase-negative *S. aureus*, stage 2: no culture). One patient was infected with a different organism at stage 2 (stage 1: coagulase-negative *S. aureus*, stage 2: methicillin-resistant *S. aureus*). One was infected with the same organism at stage 2 (stage 1: methicillin-resistant *S. aureus*, stage 2: methicillin-resistant *S. aureus*).

The mean ESR and CRP levels at the time of stage 1 were 42.0 ± 38.1 mg/dL and 8.8 ± 12.2 mg/dL, respectively (normal reference: ESR [0-27 mg/dL], CRP [0-8 mg/dL]). The mean synovial fluid leukocyte count was 24,886.5 ± 35,967.4 cells/μL. The mean time between diagnosis of infection and stage 1 was 50.0 ± 109.1 days for patients with chronic/quiescent infections. The mean duration of antibiotic administration between stages 1 and 2 was 6.6 ± 1.8 weeks.

After spacer placement, the mean time until stage 2 was 77.5 ± 38.3 days. The mean ESR and CRP at the time of stage 2 were 32.2 ± 29.8 and 2.1 ± 3.1, respectively, both of which significantly decreased from stage 1 ($P < .05$). The mean synovial fluid leukocyte count at stage 2 was 6849.2 ± 13,998.3, and exact numerical

Table 1
Baseline patient characteristics.

Characteristic	Hip cohort (n = 12)	Knee cohort (n = 30)
Age, years	60.2 ± 15.2	57.4 ± 15.2
BMI, kg/m^2	31.0 ± 7.8	30.9 ± 4.9
Male sex	7 (58.3%)	19 (63.3%)
CCI	2.6 ± 1.4	2.6 ± 2.5

CCI, Charlson Comorbidity Index.

Table 2
Bacterial pathogens cultured from the native joint.

Pathogen	N (%)
No growth from culturing tissue collected at stage 1	11 (26.2%)
Methicillin-sensitive *Staphylococcus aureus* (MSSA)	6 (14.3%)
Methicillin-resistance *Staphylococcus aureus* (MRSA)	4 (9.4%)
Coagulase (-) *Staphylococcus aureus*	10 (23.8%)
Serratia marcescens	2 (4.8%)[a]
Pseudomonas aeruginosa	1 (2.4%)
Vancomycin-resistant *Enterococcus (VRE)*	1 (2.4%)[a]
Group G *Streptococcus*	1 (2.4%)
Streptococcus viridans	2 (4.8%)
Culture results undocumented in existing charts	5 (11.9%)

[a] One patient had a positive culture for both VRE and *Serratia*.

Table 3
Clinical and functional outcome measures.

Outcome measure	Preoperative	Postoperative	*P*-value
Hip cohort			
mHHS	42.9 ± 11.8	83.3 ± 11.1	<.0001
ROM	73.8 ± 21.2	102.1 ± 11.8	<.0001
Knee cohort			
KSS	35.9 ± 16.9	80.1 ± 16.6	<.0001
KSSF	38.0 ± 15.1	71.5 ± 24.0	<.0001
ROM	90.9 ± 14.9	100.5 ± 17.1	<.0001

synovial WBC count cutoffs do not exist for native joints treated with a spacer, before reimplantation.

Functional outcome evaluation

There were significant improvements in all mean clinical outcome scores and ROM (Table 3). Multivariate linear regression models were constructed to determine the influence of (1) demographic and (2) infectious variables on functional outcomes. Age (β: −0.78, 95% confidence interval [CI]: −1.2 to −0.35; $P = .004$) was independently associated with a lower postoperative HHS in the hip cohort. No infectious factors were associated with the HHS in this cohort. Furthermore, no demographic or infectious variables were found to be independently associated with the KSS or KSSF ($P > .05$ all).

Complications

The complication rate after stage 1 was 7/42, 16.7%. This included 5 patients necessitating spacer exchange, one spacer dislocation, and one manipulation under anesthesia in a patient with a dynamic spacer with 70 degrees of preoperative knee flexion. At a mean of 3.3 ± 1.7-year follow-up, the overall complication rate was 33.3% (14/42) (Table 4). These included 2 (2/42, 4.8%) deep periprosthetic joint infections, one with *Staphylococcus epidermidis* and the other with group B *Streptococcus*—both were the same organisms identified before stage 1. Infections were treated with irrigation, debridement, and exchange of the polyethylene insert, followed by 6 weeks of IV antibiotics. One of these patients ultimately required a knee fusion from persistent periprosthetic joint infection in the setting of a poor soft-tissue envelope. A total of 4 (4/42, 9.5%) patients required manipulation under anesthesia for arthrofibrosis at the latest follow-up.

The association between complications and infection presentation (acute vs chronic) was investigated using the chi-squared test of association. This analysis revealed that there were no statistically significant associations between the number of complications and timing of infection (acute: 8 vs chronic: 6, $P = .51$).

Multivariate logistic regression models incorporating (1) demographic and (2) infectious variables were constructed to determine the influence of these variables on the incidence of complications. No demographic variables were found to be independently associated with complications. However, analysis using infectious data demonstrated that the ESR (odds ratio: 1.07, 95% CI: 1.02-1.13; $P = .043$) and CRP (odds ratio: 1.43, 95% CI: 1.21-1.88; $P = .018$) at stage 2 were independently associated with a higher likelihood of complications at the final follow-up.

Discussion

The main findings of the present study were that (1) patients with septic arthritis of the hip or knee experienced significant improvements in function after modern two-stage exchange arthroplasty at midterm follow-up with an infection cure rate of 95.2%; (2) complications were prevalent with this procedure with an incidence of 33.3%; (3) greater ESR and CRP levels at the time of the second stage of this procedure were both independently associated with a higher likelihood of experiencing a complication; and (4) increasing age was independently associated with lower HHSs in this specific two-stage exchange cohort.

The rate of complications in this study was found to be 33.3%. High rates of complications using this procedure have also been noted in previous studies [16,17]. Indeed, Chen et al. reported a reinfection rate in septic arthritis with antibiotic spacer placement of up to 14% [9] and Lum et al. [18] reported that approximately 10% of patients with septic arthritis of the native hip will need spacer exchange. This phenomenon is unsurprising as septic native joint arthritis predisposes patients to recurrent infection, knee stiffness/arthrofibrosis, and subsequent comorbidity [19]. It is likely that persistent changes to soft-tissue structure, bone quality, and local inflammation contribute to the high incidence of complications in this challenging patient population. Interestingly, the present study also identified that greater ESR and CRP levels at the time of reimplantation of components were independent risk factors for increased incidence of complications. Specifically, an elevated ESR conferred a 7% increase in the odds of developing a complication, while an elevated CRP conferred a 43% increase in the odds of developing a complication. There is currently a paucity of literature which has identified the ESR and CRP as markers of complications

Table 4
Complications during the two-stage exchange procedure.

Joint	Complication description
Hip cohort	
1	Posterior hip dislocation 3 weeks after stage 2 treated by closed reduction
2	Spacer exchange between stages 1 and 2
Knee cohort	
1	Dislocation of the spacer between stages 1 and 2
2	Spacer exchange between stages 1 and 2
3	Spacer exchange between stages 1 and 2
4	Spacer exchange between stages 1 and 2
5	Spacer exchange between stages 1 and 2
6	Instability of patellofemoral joint requiring revision 9 months after stage 2 treated with lateral release and polyethylene liner exchange
7	Developed second periprosthetic joint infection with a different organism 14 months after stage 2
8	Developed second periprosthetic joint infection with a different organism 22 months after stage 2 and fracture of medial femoral condyle
9	Arthrofibrosis requiring manipulation under anesthesia after stage 2
10	Arthrofibrosis requiring manipulation under anesthesia after stage 2; subsequently underwent arthroscopic lysis of adhesions
11	Arthrofibrosis requiring manipulation under anesthesia after stage 1
12	Arthrofibrosis requiring manipulation under anesthesia after stage 2

after two-stage exchange arthroplasties as part of the treatment algorithm for previously infected native joints treated with two-stage arthroplasty, but it is plausible that persistent elevation in these markers indicates underlying infection in the absence of systemic symptoms. This finding may have clinically significant implications in that the treating surgeon may opt to delay reimplantation or insert a second spacer in the presence of elevated ESR and CRP markers and instead continue with antibiotic treatment. This is particularly important as synovial fluid WBC count data do not exist for reimplantation of a native knee that has been treated for septic arthritis with an antibiotic spacer. Furthermore, in many cases, the WBC count is lower than the threshold for a native septic arthritis but greater than the number for a chronic infection of a prosthetic joint. Future studies are warranted to establish synovial fluid markers and concentrations in this clinical scenario.

The present study found that patients with septic arthritis of the native knee and hip experienced an infection cure rate of 95.2% and significant functional improvements at a mean 3.3-year follow-up as indicated by the mHHS, KSS, KSSF, and mean degrees of flexion after a respective total joint arthroplasty. This is consistent with previous literature that has compared the outcomes of a two-stage exchange arthroplasty with other procedures [20-22]. Nazarian et al treated 14 patients with septic knee arthritis or osteomyelitis with (1) resection arthroplasty, (2) implantation of an antibiotic nonarticulating cement spacer and antibiotic therapy, and (3) total knee arthroplasty. At a mean of 4.5 years, they reported a 100% success rate and improvement in mean KSSs from 46 to 89 points [23]. Shaikh et al. retrospectively reviewed 15 patients with septic arthritic knees and reported a 100% success rate at a mean of 4 years postoperatively. This group reported a mean improvement in ROM from 103° to 115°, KSS from 41 to 85 points, KSSF from 43 to 83 points, and the mean visual analog scale pain score decreased from 66 points to 18 points [19]. In terms of functional improvements after hip septic arthritis, Fleck et al. [13] demonstrated that the HHS improved from 11 to 67 points after articulating spacer placement and subsequently to 93 points after total hip arthroplasty at the latest follow-up. Furthermore, no patients in their series developed a reinfection.

As such, the results of our study suggest that two-stage primary arthroplasty in patients with native infections of either the hip or knee joints is an effective treatment option despite being considered challenging clinical entities. As two-stage exchange is becoming a standard of care, future studies may continue to better delineate the protocols, indications, and timing of reimplantation when using this technique to optimize outcomes and minimize the incidence of adverse events. We currently recommend the use of two-stage exchange total joint arthroplasty in select patients who present with secondary degenerative joint disease related to septic arthritis in the context of these promising results. At our institution, patients with a known history of a previously treated septic arthritis with irrigation and debridement and intravenous antibiotics have preoperative labs and joint aspirate fluid routinely checked. If within normal limits, shared decision-making is performed with respect to future arthroplasty options. However, the two-stage protocol is always recommended in the setting of uncertain previous management of their native septic joint (ie, no history of irrigation and debridement or uncertain length of antibiotic treatment), regardless of preoperative or intraoperative findings. Patients should be counseled that although they are likely to experience improvements in their clinical and functional status from their baseline state with the two-stage arthroplasty procedure, the risk of complications is high (33.3%). In addition, discussion with patients should ensure to emphasize the risk of reinfection, morbidity, and possibility of the need for additional spacer exchange as highlighted in the current series.

Limitations

Our study has several limitations, first of which is a small sample size as this limits the ability to generalize our results. However, in the literature, studies on two-stage exchange arthroplasty for septic arthritis are limited by small sample sizes, and our data are representative of that from multiple surgeons, which may help increase the external validity. This study also excluded patients who did not have a minimum of 2 years of follow-up and completion of the entire two-stage protocol, potentially excluding patients with poor outcomes secondary to mortality or inability to cure their infection, which ultimately biases the study toward better outcomes. However, all patients who began the two-stage protocol completed the protocol and none were lost to mortality during the protocol. In addition, these data were collected retrospectively, which puts the study at risk for selection bias; however, our institution controls the time period in which patients can respond to patient-reported outcome surveys, which should help limit this bias. Another limitation is in the use of the included outcome measures, as the authors recognize the limitations of using the KSS and mHHS in a native infection population as these metrics heavily weigh pain as a scoring measurement and pain resolution does not always correlate with an excellent clinical outcome. However, these outcome measures are common within the arthroplasty literature and make cross-study comparisons more reliable.

Conclusions

Patients with a history of native septic arthritis of the hip and knee, and secondary end-stage degenerative joint disease, showed significant postoperative improvements and a high rate of complications after a two-stage primary total joint arthroplasty. Despite improvements, some patients may necessitate a third operation because of the incidence of reinfection and spacer exchange. This information should be used to counsel patients who present with this challenging clinical scenario.

Conflict of interest

Brett R. Levine, MD, MD serves as a board or committee member of the AAOS and American Association of Hip and Knee Surgeons; receives research support from Artelon and Zimmer; serves as a paid consultant in Exactech, Inc, Link Orthopaedics, and Merete; and serves as an editorial or governing board member in Human kinetics and SLACK Incorporated. He is Deputy Editor of *Arthroplasty Today* and as such was recused from the blinded peer review and editorial process for this manuscript.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2020.05.012.

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