Research Article

Dual Surgical Setup Associated with Reduced Infection Recurrence for Hip and Knee Arthroplasty After Two-Stage Exchange

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ABSTRACT

Introduction: Two-stage exchange (TSE) is the gold standard for the treatment of chronic periprosthetic joint infection (PJI) after total joint arthroplasty of the hip and knee in the United States. Failure of treatment can have devastating consequences for the patient, including poor functional outcomes, multiple further surgeries, and increased mortality. Several factors associated with infection recurrence have previously been identified in the literature. The purpose of this study was to evaluate whether the use of a dual surgical setup was associated with reduced risk of recurrence after TSE for PJI.

Methods: A retrospective study was conducted between January 2000 and December 2021 to isolate patients who underwent TSE after total joint arthroplasty of the hip and knee. Failure was defined as infection recurrence requiring surgical intervention. Demographic factors (age, sex, body mass index, smoking status, American Society of Anesthesiologists status), preoperative comorbidities (hypertension, cardiac disease, diabetes status, depression diagnosis, pulmonary disease), operating surgeon, single versus dual setup, hospital setting, use of long-term antibiotics postoperatively after TSE, aspiration data, and infecting organism were compared between cohorts using multivariate regression analysis.

Results: A total of 134 patients were identified who underwent TSE after diagnosis of PJI. The mean follow-up was 67.84 (range, 13 to 236) months. Dual setup (odds ratio, 0.13; confidence interval, 0.02 to 0.52; $P = 0.0122$) was found to be an independent predictive variable associated with a lower risk of infection recurrence.

Conclusion: Utilization of a dual surgical setup is a low-cost modifiable risk factor associated with a lower risk of recurrence of after TSE of the hip and knee for PJI.

Periprosthetic joint infection (PJI) is a devastating complication after primary total joint arthroplasty (TJA) that is associated with increased mortality.[1] With the projected increasing volume of primary hip and knee TJA in the coming years, PJI is expected to pose a larger economic and clinical burden on healthcare systems, reaching $1.85 billion by 2030.[2,3] Currently, two-stage exchange (TSE) arthroplasty is the benchmark for treatment of chronic PJI in the United States. Although this treatment has been successful relative to alternative procedures, studies have reported a failure rate ranging from 10.7% to 40% at short term.[4-7] Recurrence of PJI after failed TSE is exceedingly difficult to treat with frequent conversion to girdlestone or joint arthrodesis.

Several factors have been previously associated with failure of TSE arthroplasty. These include sex, obesity, smoking, prior revision surgery, resistant staphylococcus aureus infection, and medical comorbidities including cardiac disease, psychiatric disorders, and hypoalbuminemia.[5-12] Although multiple studies have looked at preoperative factors associated with PJI recurrence, data on intraoperative risk factors are more limited. The importance of sterility of surgical drapes, instruments, gloves, and gowns has been well-established in prevention of PJI in the primary setting.[13] This is especially important when performing a revision for infection because there is a known bacterial burden within the wound that can contaminate surgical drapes, instruments, gloves, and gowns. Use of a dual surgical setup has previously been shown to decrease the risk of infection recurrence in patients undergoing débridement, antibiotics, and implant retention (DAIR).[14] However, utilization of this technique has not previously been studied in patients undergoing TSE. The purpose of this study was to evaluate whether the use of a dual surgical setup was associated with reduced risk of recurrence after TSE for PJI.

Methods

After institutional review board approval, a single hospital system database was queried from January 2000 to December 2021 for patients with a diagnosis of hip or knee PJI. Inclusion criteria included (1) surgical indication of PJI of a primary total hip arthroplasty (THA) or total knee arthroplasty (TKA) (as consistent with the 2018 International Consensus Meeting [ICM] criteria), (2) TSE procedure with the corresponding surgical note available, and (3) at least 1-year follow-up. Exclusion criteria were patients (1) with oncologic diagnosis, (2) undergoing conversion procedure, (3) with history of infection of the surgical joint, or (4) with surgical technique differing from the standard technique outlined in this study.

Patients were manually chart reviewed to confirm a diagnosis of PJI. Other variables collected were demographics (ie, age, sex, body mass index [BMI], American Society of Anesthesiologists status, and smoking status), comorbidities (History of infection [ie, site-specific osteomyelitis, superficial infection, sepsis], hypertension, ischemic heart disease, chronic obstructive pulmonary disease, diabetes mellitus, or major depressive disorder), PJI details (culture growth, ICM 2018 criteria), and surgical history (dates and indications of index arthroplasty and other revision surgeries, previous treatment with irrigation and débridement (I&D) and/or suppressive antibiotic therapy, operating surgeon, single versus dual setup). Long antibiotic use was defined as 6 or more weeks of antibiotics immediately after the second stage of the TSE. The setup of the first stage of the TSE served as the primary variable in question.

A total of 134 patients who underwent TSE for treatment of PJI of the hip or knee were included for analysis. The average age of the patient cohort was 64.1 ± 10.5 years, and 35% were women. The average BMI was 31.8 ± 7.7 kg/m², and the average ASA score of the cohort was 2.6% ± 0.6; 34% of patients were undergoing revision THA, and 66% of patients were undergoing revision TKA. The average time to reimplantation was 153 ± 108 days. The entire cohort had a mean follow-up time of 67.8 (range, 13 to 236) months (Table 1). A total of 32 surgeons performed the 134 procedures included in this study.

Dual Setup in the Setting of Two-Stage Exchange

Surgical Technique

The surgical approach used for the dual setup consisted of skin preparation with an alcohol-based skin prep and initial draping of the joint of interest as would be routine for an index arthroplasty with two split drapes under an extremity drape. An iodinated plastic film was placed over the skin and an impermeable stockinette over the distal aspect of the extremity. The draped extremity was then placed through a second "hip drape" consisting of a large opening drape with a rubber seal over the prepped and iodinated plastic drapes. A second stockinette was placed over the first. The rubber seal of the "hip drape"

Table 1. Demographics and Surgical Data of Patients Undergoing Two-Stage Exchange Arthroplasty With Single and Dual Setup

Factor	Mean/% (n = 134)	Single Setup (n = 105)	Dual Setup (n = 29)	P
Male	64.93	67.62	55.17	0.2720
Age	64.43 (34-86)	64.74 (39-86)	63.31 (34-84)	0.5619
ASA 2 (n = 127)	39.55	38.10	44.83	0.5269
3	50.75	51.43	48.28	1.0000
4	4.48	4.76	3.45	1.0000
BMI (n = 130)	31.90 ± 8.90	32.01 ± 8.90	31.53 ± 8.90	0.7961
Hip	34.33	30.48	48.28	0.0818
HTN	56.72	58.10	51.72	0.6725
Cardiac	30.60	29.52	34.48	0.6517
Lung	17.16	20.95	3.45	**0.0265**
Diabetes	17.91	20.00	10.34	0.2845
Depression	16.42	17.14	13.79	0.7832
Never smoker	48.51	52.38	34.48	0.0976
Former smoker	43.28	41.90	48.28	0.6725
Current smoker	8.21	5.71	17.24	0.0597
Stand-alone I&D	40.30	41.90	34.48	0.5265
Long antibiotics after 2-stage exchange	44.78	50.48	24.14	0.1158
Staph culture	45.52	45.71	44.83	1.0000
Resistant staph	10.45	7.62	20.69	0.0783
Multiple organisms	10.45	10.48	10.34	1.0000
Negative culture	15.67	16.19	13.79	1.0000
Time from revision to last f/u	67.84 (13-236)	76.59 (13-236)	38.55 (13-81)	**0.0232**
PJI recurrence	29.85	36.19	6.90	**0.0023**

ASA = American Society of Anesthesiologists, BMI = body mass index, f/u: follow-up, HTN = hypertension, I&D = irrigation and débridement, PJI = periprosthetic joint infection, Staph = Staphylococcus aureus. Bolded values reached statistical significance (p-value < 0.05).

created a water-tight barrier between the outer and inner drapes. If the extremity was small and this seal is not possible, thin strips of iodinated adhesive plastic were used to create this seal. After a thorough irrigation, débridement and explant of all existing components, the electrocautery, pulse lavage, suction, and light handles were removed from the field. The wound was covered with sterile sponges. The outer drapes were removed along with the outer stockinette from cephalad to caudad exposing the inner, clean surgical drapes. The outer drapes and thin strips of iodinated adhesive plastic were able to be removed carefully without tearing the underlying iodinated plastic radiograph. The outer surface of the iodoform plastic was prepped with betadine. The instrument table and outer drapes were removed from the room. The surgical team rescrubbed and donned new gowns, gloves, and hoods. A new electrocautery, pulse lavage, suction, and light handles were used along with all new surgical instruments. The sponges were removed from the incision and the wound was irrigated with 3 L of lavage before spacer insertion and wound closure.

The surgical approach used for the single setup group involved standard skin preparation with an alcohol-based skin prep and initial draping of the joint of interest in a standard fashion. An iodinated plastic film was placed over the skin and an impermeable stockinette over the distal aspect of the extremity. Once irrigation, débridement, and explant of existing components were completed, an antibiotic spacer was implanted in a standard fashion. The wound was irrigated and closed in a routine fashion.

The antibiotic spacer used consisted of an articulating or nonarticulating spacer chosen based on patient pathology. A prefabricated spacer or spacer created at the time of the operation was used based on surgeon preference. The antibiotic used was a water-soluble and thermodynamically stable antibiotic chosen based on the infecting organism, antibiotic susceptibilities, and with input from infectious disease. The spacer was constructed using no greater than 4.5 g per 40 g bag of cement.

Outcomes

The primary outcome was recurrence of PJI after TSE. Recurrence of PJI was defined as additional surgical treatment (ie, I&D, repeat two-stage). This was confirmed through orthopaedic and infectious disease notes.

Statistical Analysis

The Levene test for equality of variance was used to evaluate the variance of the data set; normality of the data was inspected visually using histograms. Continuous variables were represented as an average with a corresponding standard deviation. Categorical variables were represented as a frequency and percentage. P values for continuous and categorical variables were calculated using the independent Student t-test and chi-squared test, respectively.

Logistic regression was used to identify the factors that are associated with the outcome of PJI recurrence. Variables included in the univariate logistic regression include those in Table 1. A multivariate logistic model was created using the variables with a P value of 0.10 or less to capture all potentially notable variables. These variables included age, BMI, depression, long antibiotic use, and single versus dual setup.

All statistical analyses were performed using R (The R Foundation) and RStudio (RStudio). The P value for statistical significance was set to $\alpha < 0.05$.

Results

Seventy-eight percent of the procedures were done using a single setup, and 22% of procedures were done using a dual setup (Table 1). Eleven of the 32 surgeons performed the dual setup procedures identified.

The single setup cohort had a higher incidence of pulmonary disease as well as longer mean follow-up. There was no difference in age, ASA grade, BMI, type of surgery (hip versus knee), medical comorbidities (excluding pulmonary disease), history of previous I&D, long-term an-

tibiotics, or presence of methicillin-resistant staph aureus, polymicrobial, or culture negative infection among the groups. In total, 36.1% patients within the single setup group and 6.9% of patients within the dual setup group had PJI recurrence ($P < 0.01$). Overall, 29.9% of patients had recurrence of PJI (Table 1). Univariate logistic regression of patients with and without PJI recurrence revealed age ($P = 0.04$), BMI ($P = 0.03$), and use of a dual setup ($P < 0.01$) differed significantly between the groups (Table 2). On multivariate analysis controlling for age, BMI, pulmonary disease, use of long-term antibiotics after stage 2, follow-up time, and use of dual setup, only use of a dual setup was found to be significantly associated with a lower rate of PJI recurrence ($P = 0.01$) (Table 3).

Discussion

PJI recurrence is a devastating complication associated with increased patient mortality.[15] Although several patient factors have been identified to correlate with PJI recurrence, data on intraoperative factors influencing recurrence are more limited. In this retrospective study, we found that use of a dual surgical setup was associated with a lower rate of recurrent PJI on multivariate analysis compared with use of a single surgical setup.

Although TSE has long been considered the benchmark for the treatment of PJI with early studies demonstrating a high rate of treatment success, recent studies have questioned these results with failure rates of 28% to 40%.[7,16,17] Several factors have been associated with failure of TSE. This includes a history of failed débridement, antibiotics, with implant retention procedure as well as infections that are culture negative or caused by drug-resistant organisms, such as methicillin-resistant staph aureus or enterobacteriaceae species.[1,6,18,19] Host factors, such as male sex, advanced age, smoking, obesity, hypoalbuminemia, and medical comorbidities including diabetes mellitus, rheumatologic conditions, heart, or psychiatric and coagulation disorders have also been linked to TSE failure.[7-11,19] When considering laboratory tests taken at the time of diagnosis, a higher c-reactive protein (CRP) at the time of diagnosis has been shown to be associated with a higher probability of reinfection.[5]

Data on intraoperative surgical technique to prevent PJI recurrence when performing TSE are limited. Described techniques of one-stage exchange for PJI involve regowning, redraping, and regloving, with use of new instruments to eliminate the bacterial burden on

Table 2. Univariate Analysis for the Outcome of Periprosthetic Joint Infection Recurrence After Two-Stage Exchange

	B	Exp(B)	CI Lower 2.5%	CI Upper 2.5%	P
Male	−0.15	0.86	0.40	1.88	0.7012
Age	−0.04	0.96	0.92	1.00	**0.0393**
ASA (reference: ASA 2)					
ASA 3	0.32	1.37	0.62	3.15	0.4412
ASA 4	−0.49	0.62	0.03	4.30	0.6705
BMI	0.06	1.06	1.01	1.11	**0.0262**
Hip	−0.45	0.64	0.28	1.41	0.2794
HTN	0.34	1.41	0.66	3.05	0.3790
Cardiac	0.45	1.57	0.71	3.43	0.2600
Lung	0.51	1.66	0.63	4.19	0.2880
Diabetes	0.42	1.53	0.59	3.81	0.3680
Depression	0.59	1.81	0.68	4.63	0.2190
Smoking status (reference: never)					
Former	−0.14	0.87	0.40	1.87	0.7196
Current	−0.76	0.47	0.07	2.01	0.3545
Stand-alone I&D	0.28	1.32	0.62	2.79	0.4697
Long antibiotics after 2-stage exchange	0.73	2.08	0.99	4.47	0.0553
Staph culture	0.11	1.12	0.53	2.36	0.7643
Resistant staph	−0.49	0.61	0.13	2.10	0.4700
Multiple organisms	−0.07	0.93	0.24	3.00	0.9120
Negative culture	−0.69	0.50	0.14	1.48	0.2455
Time from revision to last f/u	0.00	1.00	1.00	1.01	0.3110
Dual setup	−2.04	0.13	0.02	0.47	**0.0074**

ASA = American Society of Anesthesiologists, BMI = body mass index, CI = confidence interval, Exp = exponent, f/u = follow-up, HTN = hypertension, I&D = irrigation and débridement, PJI = periprosthetic joint infection, Staph = Staphylococcus aureus. Bolded values reached statistical significance (p-value < 0.05).

Table 3. Multivariate Logistic Regression for the Outcome of Periprosthetic Joint Infection Recurrence After Two-Stage Exchange

Multivariate Logistic Regression, Outcome is PJI Recurrence	B	Exp(B)	CI Lower 2.5%	CI Upper 2.5%	P
Age	−0.04	0.96	0.92	1.00	0.0755
BMI	0.06	1.06	1.00	1.12	0.0513
Lung	0.53	1.71	0.58	4.86	0.3190
Long antibiotic	0.51	1.66	0.72	3.91	0.2368
Time from revision to last f/u	0.00	1.00	1.00	1.00	0.7756
Dual setup	−2.07	0.13	0.02	0.52	**0.0122**

BMI = body mass index, CI = confidence interval, Exp = exponent, f/u = follow-up, HTN = hypertension, PJI = periprosthetic joint infection. Bolded values reached statistical significance (p-value <0.05).

these surfaces that may cause contamination of the wound.[20,21] A previous study examining use of a dual setup for débridement, antibiotics, with implant retention procedures at our institution found a lower rate of recurrence while using a dual surgical setup.[22] Although antibiotic spacers are temporary and able to deliver high levels of minimum inhibitory concentrations of antibiotics into the surgical site, bacteria and biofilm may still persist.[23] Therefore, we believe that the potential for greater bacterial contamination of the wound may still predispose patients to treatment failure.

Our data demonstrated a lower risk of PJI recurrence among patients undergoing TSE with a dual setup. Demographic data, including age, sex, BMI, and medical comorbidities as well as infecting pathogen, were noted to be largely similar between patients undergoing TSE with single versus dual setup. It was noteworthy that the single setup group had longer follow-up and a higher incidence of pulmonary disease compared with the dual setup group. This is likely due to the fact that use of a dual setup for TSE is a newer practice that has grown in use at our institution over the past decade. However, after controlling for follow-up time and pulmonary disease among other variables in the multivariate analysis, the use of a dual setup was still found to be associated with a markedly lower risk of infection recurrence.

The retrospective nature of this study and limited power are notable limitations to this study. As with other studies examining infrequent complications such as PJI, prospective studies are difficult because of the rare incidence of these outcomes. Although we were able to consider numerous covariates including age, BMI, medical comorbidities, infecting organism, and previous surgery, we did not have information on prealbumin levels, race, income, thoroughness of débridement, or patients' compliance with antibiotic treatment that could potentially influence the rate of PJI. Our data were limited to hospitals within a single health system which may limit the generalizability of our study. Furthermore, our follow-up was largely limited to midterm results, with a shorter duration of follow-up for cases using a dual setup. To control for this difference in follow-up, we included follow-up time as a variable in our multivariate regression model and still found use of a dual setup to be associated with a lower likelihood of infection recurrence. As use of a dual setup is still a limited but growing practice among surgeons at our institution, the number of surgical cases using a dual setup was markedly lower than the number of cases using a single setup. Despite this difference, we note a significant difference in recurrence rate between single and dual setup cases. Additional studies should add to these existing data with a larger number of patients with longer follow-up. Our study also included cases involving numerous surgeons over a substantial period of time, and differences in surgical practice may influence recurrence rates. To best control for this, we only included surgical cases that were performed using the technique outlined in our Methods section. A greater proportion of surgeons using a dual setup were fellowship-trained arthroplasty surgeons compared with the single setup cohort (100% versus 86%), which may account for differences between the two groups. Additional studies should build on these data by collecting prospective data on a larger cohort of patients spanning multiple hospital systems.

Conclusion

This study found the use of a dual setup to be associated with a lower rate of recurrence after TSE of the hip and knee for PJI. This is a low-cost, modifiable option that may aid to improve outcomes.

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