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Original research

Does Adherence to Preoperative Surgical Selection Criteria Reduce the Rate of Prosthetic Joint Infection in Primary and Revision Total Knee Arthroplasties?

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ABSTRACT

Background: There has been recent increased focus on the importance of modifiable risk factors that can affect the risk of potentially avoidable complications such as prosthetic joint infection (PJI). We aimed to assess the relationship between adherence to a preoperative optimization protocol at our institution and its influence on the rate of PJI after primary and revision total knee arthroplasty (TKA).

Methods: A single-institution, retrospective study was conducted on all elective primary and revision TKAs performed over a 2-year period. PJI was diagnosed using the 2011 Musculoskeletal Infection Society criteria. Surgical outcomes and PJI were assessed relative to adherence to preoperative optimization criteria. Compliance was set as a binary variable with any case that did not meet all criteria deemed noncompliant.

Results: A total of 669 TKAs met inclusion criteria, including 510 primary and 159 revision TKAs. Overall compliance was 61.3%. There were 26 PJIs (3.9%) in total. The PJI rate was 1.2% (6) among primary and 14.4% (20) among revision TKAs. The rate of PJI among cases that met the preoperative optimization criteria was 2.4% (5), and the rate among cases that did not was 6.2% (21) ($P < .05$).

Conclusions: Adherence to preoperative optimization criteria may decrease the incidence of PJI after primary and revision TKA, but further study is needed to confirm the findings of this study.

Introduction

The American Academy of Orthopaedic Surgeons projects that by 2030, 30 million joint-related procedures will be performed in the United States [1]. As the number of joint replacement procedures in the United States continues to rise, so does the human and economic burden of associated complications such as prosthetic joint infection (PJI). PJI is a devastating complication of total knee arthroplasty (TKA). The incidence of PJI after primary TKA is estimated to be between 1% and 2%, and this complication creates a significant burden for both the patient and the health-care system as a whole [2,3]. Treatment of PJIs often necessitates revision surgery and is associated with substantial health-care costs. In fact, by 2020, the hospital-associated costs of PJIs are predicted to be greater than 1 billion U.S. dollars [4].

Although the risk of death after elective TKA is very low, patients undergoing 2-stage revision TKA for infection have a mortality rate as high as 21% [5]. Identification and optimization of modifiable risk factors is an important goal as up to half of all PJIs may be preventable through the application of evidence-based strategies [6]. Careful patient selection and preoperative optimization of modifiable risk factors have become targets to minimize the risk of adverse outcomes such as PJIs [7,8]. Unfortunately, best-practice screening guidelines and preoperative optimization are not part of the routine practice of all orthopaedic surgeons. However, recent changes to reimbursement in alternative payment models have resulted in an increased focus on the

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importance of patient selection to reduce costly complications in arthroplasty.

Despite literature implicating modifiable risk factors and evidence supporting implementation of preoperative optimization protocols targeting these modifiable risk factors before TKA, there are few studies that directly assess the degree of compliance to these protocols and their relationship to development of PJI. The aim of this study is to assess the relationship adherence to a preoperative optimization protocol at our institution and the rate of PJI after primary and revision TKAs.

Material and methods

A single-institution, institutional review board (IRB)–approved, and multisurgeon retrospective study was conducted on consecutive elective primary and revision TKA procedures performed at our institution from December 1, 2015, to December 1, 2017.

A total of 683 cases were identified by querying the billing records using Current Procedural Terminology codes 27447 and 27487. Fourteen cases were excluded for the following reasons: malignancy (8), trauma (ie, periprosthetic fractures) (2), lack of follow-up (1), conversion of a patellofemoral joint replacement to a TKA (1), and surgery outside of study inclusion dates (2). All revision TKA surgeries included were aseptic revisions.

Medical records were reviewed to assess the surgical outcome and compliance with preoperative optimization including the following parameters: body mass index (BMI) $\leq$40 kg/m^2, hemoglobin A1c $\leq$ 7.5%, hemoglobin $\geq$12 g/dL, albumin $\geq$3.5 g/dL, absence of tobacco use within 30 days before surgery, and completion of a decolonization protocol if a nasal polymerase chain reaction screening was positive for methicillin-sensitive *Staphylococcus aureus* or methicillin-resistant *Staphylococcus aureus*. Compliance with these criteria was encouraged but not mandatory for surgeons at our institution during the study period, and compliance was assessed retrospectively. IRB approval was obtained for the study.

Data collection and analysis

A consecutive list of all TKAs performed by all surgeons at our institution between 12/1/2015 and 12/1/2017 was obtained from the billing department as described previously. Medical records were reviewed for all patients to confirm subject eligibility, to obtain baseline characteristics, to record medical comorbidities, to assess adherence to preoperative criteria (as described previously), and to review the postoperative course to identify any infectious complications. The diagnosis of PJI was assessed for a minimum of 2 years using 2011 Musculoskeletal Infection Society criteria. All cases that had been treated as PJI but that did not strictly meet the Musculoskeletal Infection Society criteria were adjudicated by the senior authors for clarification for inclusion.

Table 2
Frequency of preoperative noncompliance in primary and revision TKA cases.

Variable	Reasons for noncompliance	
	Primary	Revision
BMI $\leq$40 kg/m^2	32	21
Tobacco within 30 days	71	27
Albumin $\geq$3.5 g/dL	54	32
Hemoglobin A1c $\leq$ 7.5%	33	14
Hemoglobin $\geq$12 g/dL	72	42
MRSA colonization	13	7

Statistical analysis

Generalized linear mixed-effects models with a logistic link were used to test the association between preoperative optimization criteria and PJI. Models included random effects that accounted for the nesting of patient within the surgeon. The model included surgeon compliance and the surgery type (primary vs revision TKA). To account for missing data, multiple imputation via predictive mean matching with 10 imputed data sets was generated for the analysis. Individual variables were imputed (eg, smoking status, BMI), and then surgical criteria were applied. To examine the impact of individual variables on risk of infection, unadjusted, accounting for only the procedure type, and adjusted (accounting for all variables) odds ratios (ORs) and their corresponding 95% confidence intervals (CIs) were estimated using the individual variables included in the preoperative criteria. These models again accounted for nesting of the surgeon within the site. All analyses were completed using R statistical software (R Foundation for Statistical Computing Vienna, Austria). An alpha of 0.05 was used for statistical significance.

Results

A total 669 primary and revision TKAs met inclusion criteria, including 510 primary and 159 revision TKAs. Patient age ranged from 18 to 95 years; most patients were aged between 18 and 65 years (61.3%) (see Table 1). The majority of the sample was female (60%). The patients on average were obese (mean BMI: 32.2). There was a statistically significant difference in age and BMI between the patients who met all preoperative optimization criteria and those who did not. The nonadherent patient cohort was on average younger (76% were between 18 and 65) and had a slightly higher BMI (33.2 in the nonadherent cohort vs 31.1 in the adherent cohort).

The compliance rate for primary TKA was 58.2% (297/510) and 43.4% (69/159) for revision TKA. Frequency of noncompliant preoperative variables in primary and revision TKAs is outlined in Table 2. There were a total of 85 cases with missing variables, including 13 for tobacco use status, 71 for albumin level, 31 for hemoglobin A1c, and 5 for hemoglobin level.

Table 1
Demographic characteristics.

Variable	Total (%)	Adherent (%)	Nonadherent (%)	*P* value
N (%)	669	410 (61.3)	259 (39.7)	
Age, y (%)				<.001
18-65	410 (61.3)	173 (52.0)	154 (75.9)	
66-85	253 (37.8)	156 (46.8)	48 (23.6)	
86-95	6 (0.9)	4 (1.2)	1 (0.5)	
Gender = male	265 (39.6)	140 (42.0)	81 (39.9)	.691
BMI, mean (SD)	32.22 (5.83)	31.11 (5.01)	33.21 (6.70)	<.001
Revision TKA	159 (23.8)	65 (19.5)	56 (27.6)	.039

Table 3
Statistical models examining adherence to preoperative screening vs nonadherence and primary vs revision TKA.

Model	*P* value	OR (95% CI)
Model 1[a]:	.0182	0.34 (0.14, 0.83)
Model 2[b]:	.1103	0.48 (0.19, 1.18)

[a] Model 1 analyzed the infection rate as a function of adherence vs nonadherence to preoperative optimization criteria.
[b] Model 2 analyzed the infection rate taking into account adherence and primary vs revision TKA.

There were 26 infections in total (3.9%). The PJI rate was 1.2% (6) among primary and 14.4% (20) among revision TKAs. The rate of PJI among cases that met the preoperative optimization criteria was 2.4% (5), and the rate among cases that did not was 6.2% (21) ($P < .05$). Results from the generalized linear mixed-effects models demonstrated a statistically significant ($P = .035$) decrease in the PJI rate (OR: 0.34, 95% CI: 0.14, 0.83) among patients who satisfied the preoperative optimization criteria compared with those who did not. When the procedure type was included in this modeling, there was a large effect size (OR: 0.48, CI: 0.19, 1.18); however, this did not reach statistical significance ($P = .11$) (Table 3).

A univariate analysis was performed to determine the effect of individual optimization criteria. This analysis was significant only for an albumin level greater than or equal to 3.5 g/dL, which was associated with a statistically significant decrease in infections ($P = .006$, OR: 0.72, CI: 0.57-0.91) (see Table 4).

Discussion

PJI represents a serious complication of TKA, which is associated with high morbidity and mortality. The mortality rate for revision of TKAs for PJI is high, and recent evidence suggests that revision of TKA for PJI is associated with higher morbidity, mortality, and health-care expenditure than revision for aseptic causes [9].

Multiple modifiable risk factors related to PJI after TKA have been characterized [10,11]. Specifically, obesity, poor glycemic control, albumin levels, tobacco use, methicillin-resistant *Staphylococcus aureus* colonization, and preoperative anemia have gained the greatest attention [10,12–16]. In our study, only hypoalbuminemia was found to be significant in the regression analysis. Other studies examining similar interventions, such as those of Nussenbaum et al. [7] and Bullock et al. [8], have reported comparable infection rates among primary TKAs. Both studies noted significant decreases in the infection rates after implementation of preoperative screening and optimization criteria. Although there have been several articles published examining the effect of preoperative optimization of patients who underwent TJA, to the best of our knowledge, no articles have been published examining preoperative optimization in revision TKA [7,8]; thus, we are unable to provide any meaningful comparisons.

The data produced by this project suggest that optimization of these patients before revision TKA is no less important than in primary TKA. It is interesting that our statistical modeling did not demonstrate a significant difference in the infection rates when considering the procedure type (ie, primary vs revision TKAs). This is despite a clinically significant difference (greater than 3x infection rate) in the revision TKA cohort. Because the incidence of PJI is low, it is possible that our study is underpowered to determine statistically significant differences in the PJI incidence between the groups. Although our study was unable to demonstrate statistical significance when accounting for the procedure type as a variable, the demonstrated effect size was clinically significant, with an OR of 0.48 and 95% CI of 0.19-1.18. These results suggest that further study may demonstrate a clinically significant association with a lower risk of PJI if repeated.

This article has several limitations. Given the retrospective nature of our project, we cannot rule out alternative explanations for differences between the groups. Furthermore, as this is a single-institution study, the results may not be generalizable to other centers. In addition, it is possible that patients who had their index surgery at our institution subsequently received care at another institution for management of a complication such as a PJI as our protocol did not have IRB approval to contact patients during the study period to determine if patients had surgeries performed at other institutions during the study period. A further limitation is our designated optimization cutoffs. The existing articles on this topic each have different criteria; for example, Nussenbaum et al. used an HbA1c ≤ 7.0, whereas other studies have identified HbA1c > 8.0 as being a risk factor for PJI [7,10]. Nevertheless, the exact point at which to draw the line remains unclear and needs further study. The decision to include consecutive both component knee revisions and exclude isolated component revisions was based on an attempt to limit the risk of confounding, as it has been demonstrated in the literature that the incidence of infection and other complications differs among each subpopulation of patients undergoing the various forms of TKA revision [17,18]. We chose to limit this risk of confounding a priori by only assessing both component knee revisions.

Table 4
Unadjusted and adjusted estimates and odds ratios for pre-operative selection criteria variables

Variable	Unadjusted[a]					Adjusted[a]				
	Estimate	SE	*P* Value	OR	95% CI	Estimate	SE	*P* value	OR	95% CI
Age, y										
19-65	Ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
66-95	0.07	0.44	.982	1.01	0.41-2.46	−0.08	0.48	.865	0.92	0.36-2.34
Gender (male v female)	0.61	0.42	.149	1.83	0.81-4.17	0.42	0.47	.367	1.52	0.61-3.82
BMI	0.01	0.03	.863	1.01	0.94-1.07	0.03	0.04	.351	1.04	0.96-1.11
Smoking	0.65	0.51	.204	1.92	0.70-5.23	0.65	0.55	.233	1.92	0.66-5.63
Alcohol	−0.03	0.47	.947	0.97	0.38-2.47	−0.32	0.51	.521	0.72	0.27-1.96
Diabetes	−0.3	0.5	.55	0.74	0.28-4.99	−0.34	0.56	.548	0.71	0.24-2.14
Albumin	−0.33	0.12	.006	0.72	0.57-0.91	−0.37	0.14	.007	0.69	0.53-0.90
HbA1c	−0.03	0.12	.78	0.97	0.76-1.22	0.04	0.13	.744	1.04	0.81-1.34
Hemoglobin	0.11	0.11	.339	1.11	0.90-1.38	0.1	0.11	.377	1.11	0.88-1.38
Decolonized	0.37	1.19	.758	1.45	0.13-15.57	−0.2	−0.2	.887	0.82	0.05-14.08

[a] Models account for the procedure type (primary vs revision).

Conclusions

Implementation of a standardized preoperative optimization protocol represents an important intervention to improve overall outcomes in primary and revision TKA. Results from this study suggest that following a preoperative optimization protocol and optimizing modifiable risk factors can decrease the risk of PJI after revision and primary TKAs. As a result of our study, we have implemented education on patient selection and optimization and have instituted monitoring and feedback to surgeons on compliance. Further prospective studies are needed to elucidate how best to implement preoperative optimization protocols among patients undergoing TKA and to determine which criteria are most influential in reducing the risk of complications.

Conflict of interest

Gregory J. Golladay, MD is the Editor-in-Chief of *Arthroplasty Today*. He recused himself from the peer review and editorial process for this manuscript, which underwent blinded peer review. He has received royalties, consulting and speaking fees and research support from and owns stock in OrthoSensor, Inc. He receives research support from Cerus and KCI. He is on the the Publications Committee of the American Association of Hip and Knee Surgeons and is on the board of the Virginia Orthopaedic Society.

References

[1] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89(4):780.
[2] Phillips JE, Crane TP, Noy M, Elliott TS, Grimer RJ. The incidence of deep prosthetic infections in a specialist orthopaedic hospital: a 15-year prospective survey. J Bone Joint Surg Br 2006;88(7):943.
[3] Koh CK, Zeng I, Ravi S, Zhu M, Vince KG, Young SW. Periprosthetic joint infection is the main cause of failure for modern knee arthroplasty: an analysis of 11,134 knees. Clin Orthop Relat Res 2017;475(9):2194.
[4] Tande AJ, Patel R. Prosthetic joint infection. Clin Microbiol Rev 2014;27(2):302.
[5] Lum ZC, Natsuhara KM, Shelton TJ, Giordani M, Pereira GC, Meehan JP. Mortality during total knee periprosthetic joint infection. J Arthroplasty 2018;33(12):3783.
[6] Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs. Infect Control Hosp Epidemiol 2011;32(2):101.
[7] Nussenbaum FD, Rodriguez-Quintana D, Fish SM, Green DM, Cahill CW. Implementation of preoperative screening criteria lowers infection and complication rates following elective total hip arthroplasty and total knee arthroplasty in a veteran population. J Arthroplasty 2018;33(1):10.
[8] Bullock MW, Brown ML, Bracey DN, Langfitt MK, Shields JS, Lang JE. A bundle protocol to reduce the incidence of periprosthetic joint infections after total joint arthroplasty: a single-center experience. J Arthroplasty 2017;32(4):1067.
[9] Boddapati V, Fu MC, Mayman DJ, Su EP, Sculco PK, McLawhorn AS. Revision total knee arthroplasty for periprosthetic joint infection is associated with increased postoperative morbidity and mortality relative to noninfectious revisions. J Arthroplasty 2018;33(2):521.
[10] Edwards PK, Mears SC, Stambough JB, Foster SE, Barnes CL. Choices, compromises, and controversies in total knee and total hip arthroplasty modifiable risk factors: what you need to know. J Arthroplasty 2018;33(10):3101.
[11] Childers CP, Siletz AE, Singer ES, et al. Surgical technical evidence review for elective total joint replacement conducted for the AHRQ safety program for improving surgical care and recovery. Geriatr Orthop Surg Rehabil 2018;9.2151458518754451.
[12] Springer BD, Parvizi J, Austin M, et al. Obesity and total joint arthroplasty: a literature based review. J Arthroplasty 2013;28(5):714.
[13] Shohat N, Tarabichi M, Tischler EH, Jabbour S, Parvizi J. Serum fructosamine: a simple and inexpensive test for assessing preoperative glycemic control. J Bone Joint Surg Am 2017;99(22):1900.
[14] Singh JA. Smoking and outcomes after knee and hip arthroplasty: a systematic review. J Rheumatol 2011;38(9):1824.
[15] Chen AF, Wessel CB, Rao N. Staphylococcus aureus screening and decolonization in orthopaedic surgery and reduction of surgical site infections. Clin Orthop Relat Res 2013;471(7):2383.
[16] Greenky M, Gandhi K, Pulido L, Restrepo C, Parvizi J. Preoperative anemia in total joint arthroplasty: is it associated with periprosthetic joint infection? Clin Orthop Relat Res 2012;470(10):2695.
[17] Galat DD, McGovern SC, Larson DR, Harrington JR, Hanssen AD, Clarke HD. Surgical treatment of early wound complications following primary total knee arthroplasty. J Bone Joint Surg Am 2009;91(1):48.
[18] Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res 2010;468(1):45.