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Original Research

Limiting the Surveillance Period to 90 Days Misses a Large Portion of Infections in the First Year After Total Hip and Knee Arthroplasty

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ABSTRACT

Background: In 2013, the Centers for Disease Control and Prevention reduced the periprosthetic joint infection (PJI) surveillance period from 1 year to 90 days for total hip (THA) and knee arthroplasty (TKA). Our aim was to determine how the reduced surveillance window impacts capture of PJIs.
Material and methods: Primary and revision THA and TKA cases were retrospectively identified in a statewide registry from October 1, 2015, to September 30, 2018. Infections were defined using the Periprosthetic Joint/Wound Infection measure (Centers for Medicare and Medicaid Services). We compared the cumulative incidence of infected primary and revision THA (pTHA/rTHA) and TKA (pTKA/rTKA) at 0-90 days and 91-365 days postoperatively.
Results: A total of 136,491 patients were included, 59.59% female, mean age 65.8 years, and mean body mass index 32.3 kg/m^2. The overall rate of PJI diagnosed by 1 year was 1.33%. The percent of infections diagnosed between 0-90 days and 91-365 days were pTHA 76.78% and 23.22%, rTHA 74.12% and 25.88%, pTKA 57.67% and 42.33%, and rTKA 53.78% and 46.22%, respectively. More infections were diagnosed after 90 days in pTKA than in pTHA and in rTKA than in rTHA ($P < .0001$). There was a higher risk of infection throughout the year when comparing rTKA to rTHA ($P = .0374$) but not when comparing pTKA to pTHA ($P = .0518$).
Conclusion: A substantial portion of infections are missed by the 90-day surveillance period. More infections are missed after TKA than after THA. Extension of the surveillance period would allow for identification of opportunities for quality improvement.
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Introduction

Periprosthetic joint infection (PJI) remains at the forefront of serious complications related to primary and revision total joint arthroplasty (TJA). PJIs are associated with a number of adverse sequelae, including increased mortality in the perioperative period, lower reported quality of life postoperatively, prolonged hospital stay, higher rates of readmission, and increased cost to the health-care system [1–4]. Infection is the most common reason for revision in total knee arthroplasty, making up 16.8% of revisions [5]. PJI is the third most common cause of total hip arthroplasty revision, representing 14.8% of cases [6]. Recent studies have shown that the incidence and prevalence of PJIs in total hip (THA) and knee arthroplasty (TKA) are on the rise in the United States due to a number of patient-related factors and increasing presence of comorbid conditions in the arthroplasty patient population [7,8].

The Centers for Disease Control and Prevention (CDC) require hospitals to track and report surgical site infection (SSI) data. This monitoring allows for national estimates of SSIs and evaluation of interventions implemented to reduce rates of SSI. In 2013, the CDC updated the National Healthcare Safety Network surveillance definition for SSIs in order to simplify the surveillance process and reduce resource utilization [9]. This update decreased the surveillance period from 1 year to 90 days for all surgical procedures, including THA and TKA. This has raised concerns about missed cases of PJI. Some argue that surveillance over extended periods of time has a significant resource burden to the health-care system

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without much improvement in case detection [10,11]. However, 1 study evaluating the impact of the limited surveillance period found that over 20% of SSIs after bone and joint procedures were excluded from identification when using the 90-day limit [12]. More specifically, nearly 25% of PJIs occur well after the current 90-day surveillance period [13,14]. The aim of this study was, therefore, to determine how the reduced SSI surveillance window impacts the capture of PJIs for quality improvement using a large, statewide administrative claims database. We hypothesized that a substantial portion of primary and revision TKA (pTKA/rTKA) and THA (pTHA/rTHA) infections are missed by a 90-day surveillance period. Our secondary hypothesis was that more TKA infections than THA infections would be diagnosed after 90 days.

Material and methods

The institutional review board "not regulated" status was obtained prior to initiation of this study. Background information on the Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI), data sources, and variables collected have been previously described [15]. This is a multihospital consortium, through which all elective THAs and TKAs at participating sites are entered into a registry with clinical laboratory values and preoperative, perioperative, and postoperative information. The Michigan Inpatient Database (MIDB) of the Michigan Health and Hospital Association Service Corporation was used to obtain administrative codes for diagnoses and events occurring at the index hospital, as well as at external hospitals within the state, over the entire year after surgery. Patients who left the state of Michigan would be lost to follow-up; however, this is likely to be a rare scenario [16].

Patients included in our study were enrolled in MARCQI and underwent pTHA, rTHA, pTKA, or rTKA within a 3-year time period of October 1, 2015, to September 30, 2018, with 1-year follow-up through September 30, 2019. This was the most recent data set available for analysis at the time of this study. A total of 136,491 pTHA, rTHA, pTKA, and rTKA cases were identified for inclusion. Exclusion criteria included cases without 1-year follow-up, in-hospital deaths, and bilateral cases (Fig. 1). Infections were then identified following the Periprosthetic Joint/Wound Infection measure, developed for the Centers for Medicare and Medicaid Services by the Yale New Haven Health Services Corporation Center for Outcomes Research and Evaluation [17]. The use of the MIDB ensured capture of infections that presented to a different hospital than the hospital where the primary surgery was performed. The linked patient capture rate of MARCQI to MIDB was 98.42% over the study period. Infection identification began at the date of surgery and was identified during subsequent admissions up to 365 days following discharge from the index surgery. Demographic data and patient characteristics were collected through MARCQI.

Statistical analysis

The distributions of variable were examined prior to the analysis, and a survival analysis approach was used. Descriptive statistics of the patient population were compared with Kruskal-Wallis and Chi-squared testing. We calculated the cumulative incidence of infected pTHA, rTHA, pTKA, and rTKA cases at 0-90 days and 91-365 days postoperatively. The differences in infection rate for TKA compared to THA before and after 90 days were analyzed, and the 95% confidence intervals (CIs) with Chi-squared P values were reported for both primary and revision cases. A 2-sided P value < .05 was used to determine statistical significance. The cumulative percent infection and dynamic hazard rate of infections over time (hazard function) were stratified by TKA and THA after

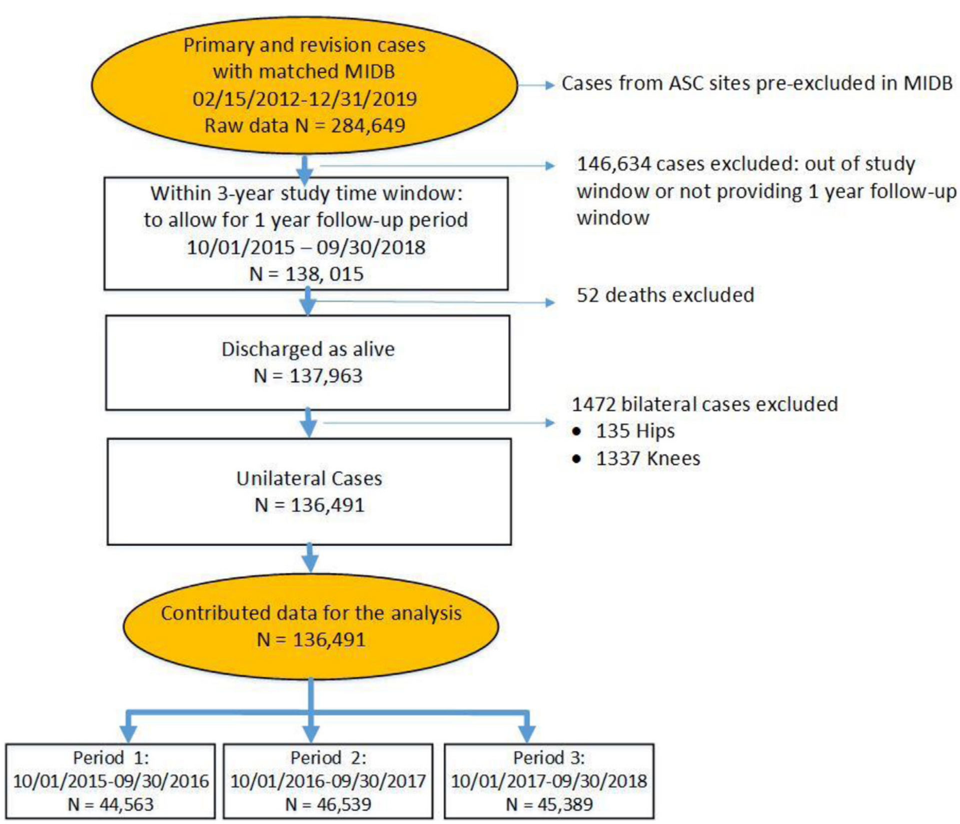

Figure 1. Flow chart of cases included for analysis. ASC, Ambulatory Surgery Center.

Table 1
Descriptive statistics of study population, separated by surgery.

Variables	Overall	Primary TKA	Primary THA	Revision TKA	Revision THA	P value, primary vs revision cases
	N = 136,491 (%)	N = 79,270 (%)	N = 46,399 (%)	N = 6946 (%)	N = 3876 (%)	
Period 1: 10/01/2015-09/30/2016	44,563 (32.65)	26,107 (32.93)	14,981 (32.29)	2210 (31.82)	1265 (32.64)	
Period 2: 10/01/2016-09/30/2017	46,539 (34.10)	27,341 (34.49)	15,625 (33.68)	2327 (33.50)	1246 (32.15)	
Period 3: 10/01/2017-09/30/2018	45,389 (33.25)	25,822 (32.57)	15,793 (34.04)	2409 (34.68)	1365 (35.22)	
BMI (kg/m^2): mean (standard deviation)	32.3 (6.8)	33.3 (6.8)	30.5 (6.3)	33.5 (7.2)	30.1 (6.7)	$P < .001$ pTHA vs rTHA[a]; $P = .1398$ pTKA vs rTKA[a]
Age (y) ≥65	76,452 (56.01)	45,815 (57.80)	24,510 (52.82)	3773 (54.32)	2354 (60.73)	$P < .0001$ pTHA vs rTHA[b]; $P < .0001$ pTKA vs rTKA[b]
Female	81,200 (59.49)	49,538 (62.49)	25,281 (54.49)	4183 (60.22)	2198 (56.71)	$P = .0077$ pTHA vs rTHA[b]; $P = .0002$ pTKA vs rTKA[b]
Smoking						
Current	15,514 (11.37)	7656 (9.66)	6474 (13.95)	807 (11.62)	577 (14.89)	$P = .0004$ pTHA vs rTHA[b]; $P < .0001$ pTKA vs rTKA[b]
Never	67,869 (49.72)	40,934 (51.64)	21,885 (47.17)	3358 (48.34)	1692 (43.65)	
Previous	52,780 (38.67)	30,491 (38.47)	17,948 (38.68)	2760 (39.74)	1581 (40.79)	
Unknown	327 (0.24)	188 (0.24)	92 (0.20)	21 (0.30)	26 (0.67)	
ASA score						
I	2242(1.64%)	1042 (1.31%)	1098 (2.37%)	74(1.07%)	28(0.72%)	$P < .0001$ pTHA vs rTHA[b]; $P < .0001$ pTKA vs rTKA[b]
II	65,959 (48.34%)	37,555 (47.39%)	24,382 (52.56%)	2614 (37.64%)	1408 (36.33%)	
III	66,117 (48.45%)	39,583 (49.95%)	20,230 (43.61%)	4039 (58.17%)	2265 (58.44%)	
IV	2133(1.56%)	1061(1.34%)	680(1.47%)	217(3.13%)	175(4.51%)	

BMI, body mass index; ASA, American Society of Anesthesiologists.
[a] Kruskal-Wallis Test.
[b] Chi-squared test.

discharge and estimated with log rank survival analysis (SAS LIFETEST).

In order to further evaluate and validate the longitudinal consistency of the infection rates, the analysis was performed for the entire time frame (all cases from October 01, 2015, to September 30, 2018) and for 3 time periods separately (period 1: October 01, 2015, to Spetember 30, 2016; period 2: October 01, 2016, to September 30, 2017; period 3: October 01, 2017, to September 30, 2018). SAS 9.4 (SAS Institute Inc., Cary, NC) was used to conduct all the analyses, including exploratory data analysis and the survival analyses, and SAS/GRAPH was used to build all figures.

Results

A total of 136,491 patients were included for analysis, with 59.59% being female, a mean age of 65.8 years, and a mean body mass index of 32.3. Differences in descriptive characteristics between pTHA/rTHA and pTKA/rTKA can be found in Table 1. On average, rTHA patients were 2.5 years older ($P < .0001$) than pTHA patients, and pTKA patients were 0.74 years older ($P < .0001$) than rTKA patients. Body mass index was 0.49 higher in pTHA than that in rTHA ($P < .0001$) and 0.21 kg/m^2 higher in rTKA than that in pTKA ($P = .0137$). A higher percentage of patients were current smokers in revision procedures vs primary procedures (11.62% rTKA vs 9.66% pTKA, and 14.89% rTHA vs 13.95% pTHA). In addition, a higher percentage of patients had a greater American Society of Anesthesiologists score in the revision category than in primary procedures in both knee and hip cases (Table 1).

The rates of PJI diagnosis by surgery, period, and relationship to the 90-day capture period can be found in Table 2. The overall rate of PJIs diagnosed by 1 year for all 3 study periods was 1.33%, with 0.94% for pTHA, 1.05% for pTKA, 4.39% for rTHA, and 5.33% for rTKA. After pTHA, 76.78% of infections were diagnosed between 0 and 90 days postoperatively, and 23.22% were diagnosed between 91 and 365 days. After rTHA, 74.12% of infections were diagnosed between 0 and 90 days postoperatively, and 25.88% were diagnosed between 91 and 365 days. For pTKA, 57.67% of infections were diagnosed between 0 and 90 days postoperatively, and 42.33% were diagnosed between 91 and 365 days. After rTKA, 53.78% of infections were diagnosed between 0 and 90 days postoperatively, and 46.22% were diagnosed between 91 and 365 days. The percentage of primary hip PJIs diagnosed between 91 and 365 days postoperatively increased from 17.93% to 27.64% from period 1 to period 3, respectively. Figure 2 shows the percent of infections diagnosed within 90 days and those diagnosed from 91 to 365 days over the 3-year study period for pTKA, rTKA, pTHA, and rTHA. More infections were diagnosed after 90 days in pTKA than in pTHA (0.45%, 95% CI 0.40-0.50 vs 0.22%, 95% CI 0.18-0.27, $P < .0001$), as well as in rTKA compared to rTHA (2.53%, 95% CI 2.17-2.94 vs 1.17%, 95% CI 0.85-1.57, $P < .0001$). More infections were diagnosed within 90 days in pTHA than in pTKA (0.72%, 95% CI 0.64-0.80 vs 0.61%, 95% CI 0.55-0.66, $P = .016$) but not in rTHA compared to rTKA (3.25%, 95% CI 2.69-3.81 vs 2.86%, 95% CI 2.49-3.28, $P = .2595$).

The cumulative percent infection within 1 year for all 3 time periods for pTKA/pTHA and rTKA/rTHA can be seen in Figures 3 and 4, respectively. There is a sustained risk of infection out to 1 year in both primary and revision cases. The hazard function for the instantaneous risk of infection per day over 1 year for combined data from all 3 time periods for pTKA compared to pTHA was not statistically different (log rank P value = .0518). There was a significantly higher instantaneous risk of infection in rTKA than in rTHA (log rank P value = .0374).

Discussion

Infection monitoring after THA and TKA is critical for tracking trends and recognizing opportunities for quality improvement, evaluating the efficacy of new protocols, and determining proper resource allocation. In 2013, the CDC reduced SSI surveillance from 1 year to 90 days for hip and knee arthroplasty [9]. England [18], Canada [19], and the European Center for Disease Prevention and Control [10] similarly recommend a 90-day surveillance period in their national guidelines. We sought to determine how this limited surveillance period impacts the capture of infection after pTHA,

Table 2
Infection rates in the study population, broken down by time period and surgery.

Time window	Surgeries	Deep infection	Diagnosis in 0-90 d	Diagnosis in 91-365 d
	N	N (%)	N (%)	N (%)
Overall (3 y) 10/01/2015-09/30/2018	Primary THA N = 46,399	435 (0.94)	334 (76.78)	101 (23.22)
	Primary TKA N = 79,270	834 (1.05)	481 (57.67)	353 (42.33)
	Revision THA N = 3876	170 (4.39)	126 (74.12)	44 (25.88)
	Revision TKA N = 6946	370 (5.33)	199 (53.78)	171 (46.22)
Period 1: 10/01/2015-09/30/2016	Primary THA N = 14,981	145 (0.97)	119 (82.07)	26 (17.93)
	Primary TKA N = 26,107	278 (1.06)	163 (58.63)	115 (41.37)
	Revision THA N = 1265	50 (3.95)	36 (72.00)	14 (28.00)
	Revision TKA N = 2210	122 (5.52)	63 (51.64)	59 (48.36)
Period 2: 10/01/2016-09/30/2017	Primary THA N = 15,625	167 (1.07)	126 (75.45)	41 (24.55)
	Primary TKA N = 27,341	278 (1.02)	164 (58.99)	114 (41.01)
	Revision THA N = 1246	61 (4.90)	48 (78.69)	13 (21.31)
	Revision TKA N = 2327	125 (5.37)	70 (56.00)	55 (44.00)
Period 3: 10/01/2017-09/30/2018	Primary THA N = 15,793	123 (0.78)	89 (72.36)	34 (27.64)
	Primary TKA N = 25,822	278 (1.08)	154 (55.40)	124 (44.60)
	Revision THA N = 1365	59 (4.32)	42 (71.19)	17 (28.81)
	Revision TKA N = 2409	123 (5.11)	66 (53.66)	57 (46.34)

rTHA, pTKA, and rTKA using a large, statewide registry, focused on quality-improvement efforts and incorporating an administrative claims database.

Our results show that over 20% of pTHA and rTHA infections and over 40% pTKA and rTKA infections are diagnosed between 91 days and 1 year postoperatively. This raises questions about the current surveillance recommendations and has implications for quality-improvement efforts directed at reducing infection. The optimal infection surveillance period after TJA is controversial in the literature, with some stating that 90 days is sufficient for PJI monitoring [20], while others recommend extended surveillance [21]. One significant factor in the recommendation for 90-day surveillance in the United States is the focus on reducing 90-day readmission after TJA due to the implementation of bundled payments to hospitals and surgeons, as well as individual hospital quality metrics with financial penalties for early readmissions [22]. This also raises the concern that a 90-day monitoring period could influence behavior regarding the timing of infection diagnoses.

In response to the reduced surveillance window, Roth et al. published a study on the rates of hip and knee arthroplasty infection using the Canadian Nosocomial Infection Surveillance Program and note that a surveillance period of 90 days would detect the

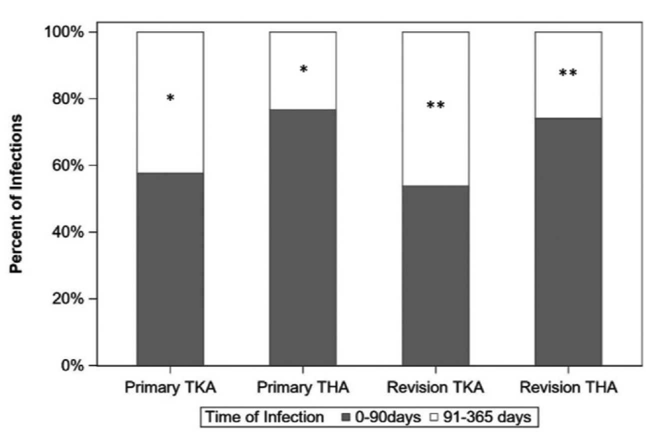

Figure 2. Percent of infections captured from 0 to 90 days and from 91 to 365 days for primary TKA, primary THA, revision TKA, and revision THA; *infections diagnosed 91-365 days, primary TKA > primary THA ($P < .0001$); ** infections diagnosed 91-365 days, revision TKA > revision THA ($P < .0001$).

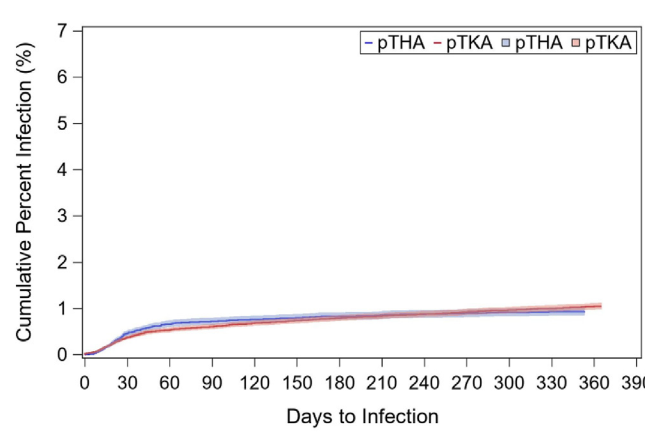

Figure 3. Cumulative percent infection with 95% confidence interval within 1 year for primary TKA and THA for all 3 periods combined. The risk of infection throughout the year was not statistically different for primary TKA vs THA (log rank P value = .0518). Y-axis matched with Figure 4 for visual comparison.

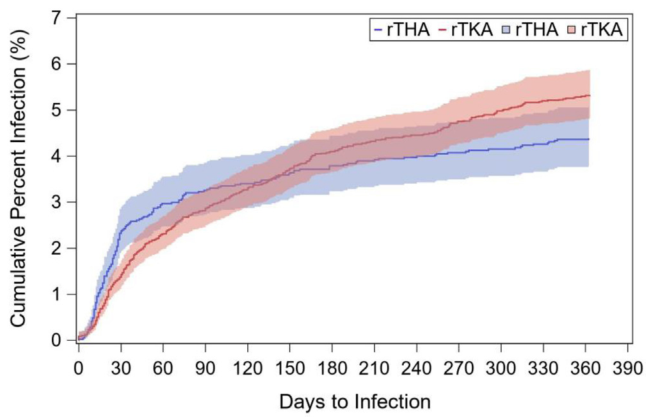

Figure 4. Cumulative percent infection with 95% confidence interval within 1 year for revision TKA and THA for all 3 periods combined. The risk of infection throughout the year was greater for revision TKA vs THA (log rank *P* value = .0374). Y-axis matched with Figure 3 for visual comparison.

majority of infections after pTHA and pTKA [21]. However, they caution that over 10% of deep infections may be missed and recommend extension of the surveillance period to 180 days in order to more accurately estimate this complication. In contrast, a study on pTHA and pTKA using Medicare data found that only 58% of PJIs were detected in the first 90 days [23], which is an even lower capture rate than the present report. The differences in infection rates and timing of diagnosis may be a result of regional preferences for patient follow-up or variations in arthroplasty protocols and patient characteristics. Regardless of these differences, our study highlights that a substantial percentage of infections are not captured by the current surveillance period, which has significant implications for the estimation of the impact of PJIs on health care, reimbursement, surgeon and hospital improvement, and society.

A notable finding is the sustained risk of infection out to 1 year in both revision and primary cases. Although an extension of the surveillance period to 1 year would require more resource allocation, our data show that the risk of infection after 90 days persists out to 1 year, and choosing a surveillance period between 90 and 365 days will still result in missing a portion of the data. In order to fully capture these infections and track trends while identifying opportunities for quality improvement, these data suggest that infection surveillance should be extended back to 1 year after pTHA, rTHA, pTKA, and rTKA, the previous CDC recommendation. Infections that occur between 90 days and 1 year are still considered to have an etiology associated with the surgical procedure and have a different microbial differential [24]. The main criticisms of a 1-year surveillance period include increased financial and personnel requirements as well as a delay in data reporting and subsequent implementation of action plans [10,11]. However, the use of administrative data from existing data sources reduces much of the burden of data collection. The current surveillance window may limit opportunities for quality improvement that may be missed with this 90-day window. These quality-improvement opportunities could ultimately reduce the incidence of PJIs and have significant implications on costs and patient outcome. For example, Premkumar et al. estimated an annual hospital cost burden in the United States of over $1.8 billion for THA and TKA PJIs [25].

Interestingly, we found a longer time to PJI diagnosis in TKA than it is in THA, which has been previously noted [26]. This is likely due to differences in the postoperative course. A typical hip-replacement patient recovers more quickly, and therefore, any early change may be more easily detected. In contrast, the postoperative knee replacement can remain painful, warm, and swollen for weeks, and progress may be slowed by hemarthrosis or pain exacerbated during physical therapy. These factors can complicate a clinician's ability to differentiate the expected postoperative course from a developing infection [26].

This study is not without limitations. Postoperative infection is an uncommon complication of TJA, so the overall incidence is small. This study includes a large sample size with data demonstrated to be consistent over a 3-year period which strengthens our findings. Another limitation is that the data were analyzed retrospectively, using an administrative claims database. These databases have been noted to be discordant from registry data in terms of complication detection after primary TJA [27]. In contrast, large administrative data sets have also been recommended for improved infection detection and tracking of patient encounters [20]. The administrative data set used in this analysis is also used by CMS and federal agencies for hospital benchmarking and, therefore, is an accurate representation of metrics provided to individual hospitals. It is possible that some infections may have been missed, including patients that left the state or those not captured by MARCQI and MIDB, or infections not captured by the administrative definition. However, this is likely very uncommon given the robust nature of the databases and rarity of the complication. There is also a low rate of out-of-state migration within 1 year of TJA reported by Etkin et al. [16], so this would be unlikely to impact the data in a meaningful way. Lastly, it can be argued that surveillance longer than 1 year will continue to capture infections. The previous recommendation was 1 year, and with the etiology of the infection still related to the arthroplasty up to 1 year, we consider this to be an appropriate time period.

Conclusion

A 90-day surveillance period misses over 20% of pTHA and rTHA postoperative infections and over 40% pTKA and rTKA postoperative infections. Given the sustained risk present throughout the first year, it is suggested that the surveillance period be extended to 1 year to appropriately capture the true infection burden and allow for implementation of appropriately directed quality-improvement efforts. If limited resources require selective extension of the surveillance period, pTKA and rTKA should be the focus of extended surveillance since diagnosis of infection is more likely to occur after 90 days in knees than in hips. Further studies should be undertaken to corroborate these findings with alternative databases.

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Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

B. Hallstrom is a committee member for Data Committee of the AAOS American Joint Replacement Registry.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.04.009.

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