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Does Operative Time Affect Infection Rate in Primary Total Knee Arthroplasty?

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Abstract
Background Prolonged operative time may increase the risk of infection after total knee arthroplasty (TKA). Both surgeon-related and patient-related factors can contribute to increased operative times.
Questions/purposes The purpose of this study was to determine (1) whether increased operative time is an independent risk factor for revision resulting from infection after TKA; (2) whether increasing body mass index (BMI) increased operative time; and (3) whether increasing experience substantially decreased operative time.
Methods We retrospectively evaluated primary TKAs from our joint registry between March 2000 and August 2012. Cox proportional hazard models were used to assess the relationship between operative time and revision resulting from infection after accounting for age, sex, BMI, and Agency for Healthcare Research and Quality comorbidity score. Of 9973 instances of primary TKA, 73 underwent revision surgery for infection (0.73%).
Results After accounting for the confounders of age and sex, operative time was not found to have a significant effect; a 15-minute increase in operative time increased the hazard of revision resulting from infection by only 15.6% ($p = 0.053$; 95% confidence interval, 0.0%–34.0%). In addition, a five-unit increase in BMI was found to increase mean operative time by 1.9 minutes, on average, regardless of sex ($p < 0.0001$). Operative time decreases with increasing experience but appears to plateau at approximately 300 surgeries.
Conclusions Operative time is only one of many factors that may increase infection risk and may be influenced by numerous confounders. Increasing BMI increased operative time but the effect was modest. The effect of increasing experience on operative duration of this common procedure was surprisingly limited among our surgeons.
Level of Evidence Level III, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at HealthEast Hospitals, St Paul, MN, USA.

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Introduction

Prosthetic joint infection (PJI) after TKA is a serious complication that can drastically affect patients' lives [31, 33]. PJI may lead to multiple operations with attendant morbidity, prolonged convalescent periods, and persistent pain and disability [31]. PJI also adds to the economic and psychological burden of the patient [7, 12, 30, 34]. Especially in the elderly population, PJI may result in a higher incidence of mortality as well [18, 32]. Hence, it is imperative to continue research strategies that minimize or prevent PJI.

Correlation of risk factors that predispose patients to deep PJI after modern TKA is critical to establish strategies to avoid this complication. Prolonged operative time may increase the risk of PJI [19, 23], perhaps as a result of increased wound contamination, increased damage to wound cells and the local environment (bleeding, cautery, suture), or some combination of these factors [3]. Both surgeon-related and patient-related factors can contribute to increased operative times. Apart from operative time, other surgeon-related factors associated with PJI after TKA include surgeon case volume [14] and use of antibiotic-impregnated cement [20]. Reported patient factors include male sex [13], preoperative comorbidities [13], diabetes mellitus [17], obesity [10, 15, 28], rheumatoid arthritis [26], and previous fractures about the knee [9]. Previously, the 75th percentile of duration of the operation has been used to delineate between operations of short and long duration [4]. However, there are few reports documenting the relationship between prolonged operative time and deep infection resulting in revision surgery after TKA [21–23] and also relatively few that describe which factors might result in prolonged operative times [11, 15, 16]. A large community joint registry with numerous surgeons performing this common procedure may better address these issues than smaller retrospective studies from high-volume academic centers.

We used our established community joint registry database to determine (1) whether increased operative time is an independent risk factor for revision resulting from infection after TKA; (2) whether increasing body mass index (BMI) increased operative time; and (3) whether increasing experience decreased operative time.

Patients and Methods

The HealthEast Joint Registry (HEJR) prospectively tracks hip and knee arthroplasties performed by over 95 surgeons at five community hospitals in the St Paul, MN, USA, metropolitan area since 1991. Details of the data collection methods and application of statistical analyses in the HEJR have been previously reported. The registry has multiple internal checks to ensure accurate data entry, has been validated, and captures approximately 94% of the primary procedures that are revised [6].

In this study, we retrospectively reviewed 9973 primary TKAs collected in the HEJR between March 1, 2000, and August 31, 2012, to identify all that had undergone subsequent revision for infection.

Unicompartmental and revision TKAs were excluded as were bilateral surgeries as a result of inconsistencies in how the operative time was recorded for each knee. One hundred twenty records with missing operative times or operative times of < 30 minutes or > 200 minutes were excluded after record review showed the majority of those times to be erroneously recorded.

Operative time was recorded as the time from skin incision to dressing placement in each case. Revisions for infection were defined as any infection that resulted in the exchange of any TKA component. The primary outcome was revision resulting from infection to a TKA. Data were also collected on age, sex, BMI, and Agency for Healthcare Research and Quality (AHRQ) comorbidity score. The AHRQ score summarizes comorbidities based on the diagnosis coding of the International Classification of Diseases, 9th Revision, Clinical Modification [5, 23]. BMI was classified as normal (< 25 kg/m^2), overweight or obese (25–40 kg/m^2), or morbidly obese (> 40 kg/m^2).

Of 9973 primary TKAs, 73 underwent revision surgery for infection (0.73%). The average age was 66.2 years (SD = 10.6), average AHRQ score was 1.36 (SD = 1.07; range, 0–7), 64% were female, and 16.1% were classified as morbidly obese (BMI > 40 kg/m^2). A total of 27.5% of the BMI scores were not available in the electronic HEJR database. Missing values were classified as a separate category and were still included in the analysis.

We compared these variables for infected versus noninfected TKAs using t-tests to compare continuous variables (operative time, AHRQ score, and age) and Fisher's exact tests to compare categorical variables (sex and BMI). We used Cox proportional hazards regression to determine whether increased operative time is a risk factor for revision resulting from infection after TKA using only operative time in the model and considering AHRQ score, age, sex, and BMI as possible confounders. Graphs and chi-square statistic based on the Shoenfeld residuals showed no evidence of a violation to the proportionality assumption in any of the models we examined [29].

A univariate Cox proportional hazards model, which did not consider any possible confounders, showed operative time to be a risk factor for revision resulting from infection; specifically, a 15-minute increase in operative time slightly increased the hazard of revision resulting from infection by 16.5% on average (p = 0.034; 95% confidence interval [CI],1.2%–34.1%). A multivariate Cox proportional hazards model was then studied, which initially included BMI, AHRQ score, age, and sex as covariates. BMI and AHRQ score were eliminated from the model in a backward stepwise manner. The final model included operative time, age, and sex.

To explore the relationship between BMI and operative time, and to test whether that relationship differed by sex, BMI was treated as a continuous variable rather than being grouped into categories. Patients with missing BMI or a BMI of > 100 kg/m^2 were excluded from this analysis, leaving 7222 patients.

The relationship between operative time and surgeon experience was also analyzed. Surgeon experience was measured as the number of primary TKAs performed at HealthEast hospitals, although some surgeons also performed TKA surgery outside HealthEast. Operative time was measured by averaging operative time per TKA for each surgeon on a monthly basis. Surgeon experience was plotted (x-axis) versus operative time (y-axis) and a smoothing spline was fit to the data.

Analyses were performed using SAS (Cary, NC, USA) and R Statistical Software (Vienna, Austria).

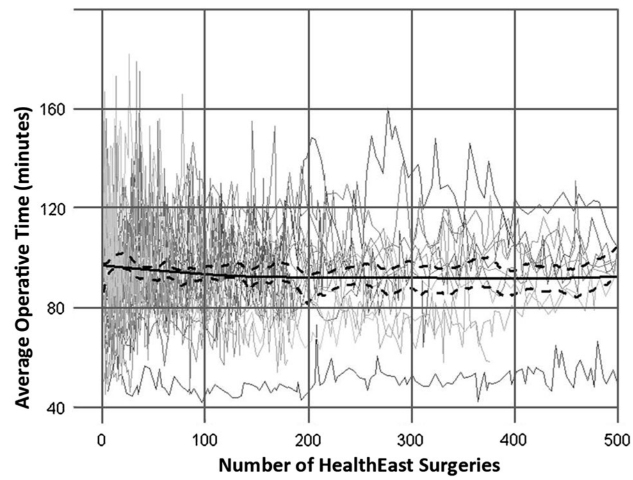

Fig. 1 Average operative time versus number of HealthEast surgeries. Average operative times for each surgeon are connected with a line, shown in grayscale. The solid black line is the smoothing spline fit to the data. The dashed black lines show 95% pointwise CIs computed using a bootstrap method.

Results

The mean operative time for noninfected cases was 93.8 minutes and the mean time for infected cases was 99.4 minutes ($p = 0.074$). After controlling for the confounding variables of age and sex, we did not find significant evidence that increased operative time increased the hazard of revision resulting from infection; a 15-minute increase in operative time increased the hazard of revision resulting from infection by only 15.6% on average ($p = 0.053$; 95% CI, 0.0%–34.1%). Controlling for age, males had a hazard of revision resulting from infection 1.9 times that of females ($p = 0.006$). Controlling for sex in this model, older patients had significantly higher hazard of revision resulting from infection with a 1-year increase in age corresponding to a 2.8% increase in hazard ($p = 0.017$).

Multiple regression showed that a five-unit increase in BMI corresponds to a 1.9-minute increase in operative time on average ($p < 0.0001$; 95% CI, 1.6–2.2) regardless of sex; operative time on average is 10.2 minutes longer for males than females with the same BMI ($p < 0.0001$; 95% CI, 9.2–11.3).

It was observed that operative time decreases slightly with increasing experience and appears to plateau at approximately 300 primary TKAs (Fig. 1). Initially, surgeons average 97 minutes per procedure, which decreases to roughly 92 minutes by 300 procedures and remains relatively static thereafter.

Discussion

Although a prolonged duration of surgery may certainly be related to the complexity of the individual case, it also allows for prolonged exposure to microorganisms in the operating environment [5]. The duration of the operation is a component of the US National Nosocomial Infection Surveillance risk index, which is widely used as a means of risk-stratifying surgical site infection (SSI) surveillance data. Because the length of an operation may reflect not only factors intrinsic to the patient, but also the influence of extrinsic factors surrounding the operation, locally defined operative times may be a better predictor of the risk of SSI inherent in the local setting [2]. However, there are relatively few data on this question [15, 21, 23, 27], and none to our knowledge from large community joint registries, which might best reflect how most arthroplasties are done. Likewise, risk factors for prolonged surgical times and learning curve effects have, to our knowledge, not been explored in the setting of a community joint registry. We thus used our community arthroplasty register to determine (1) whether increased operative time is an independent risk factor for revision resulting from infection after TKA; (2) whether increasing body mass index increased operative time; and (3) whether increasing experience decreased operative time.

Any joint registry study has inherent limitations. First, revision for infection is a relatively crude outcome measure. We cannot identify patients who may have had a superficial wound infection treated with oral antibiotics or local débridement. Likewise, we do not identify patients who may have been too medically infirm to undergo a revision procedure for infection, who declined revision surgery despite an infected TKA, or who may have undergone amputation or fusion for infection. However, the latter procedures are rarely indicated for the first-time complication of infection in primary TKA, and the medically infirm may undergo polyethylene exchange and antibiotic suppression, in which case they were included in the database. Additionally, the possibility exists that patients may have had revision TKA for infection performed elsewhere, which would not be included in our study. Prior analysis of our registry suggests a 94% capture rate with only 6% of patients undergoing revision outside our capture [6], similar to the Scandinavian registries. Patients with an initial diagnosis of an infected TKA requiring revision likely present to their original surgeon, group, or hospital for treatment, but we could not test that assumption. The BMI data were hampered to some extent by missing values. We must also acknowledge that the surgeon experience only reflected the experience within our healthcare system; many surgeons also performed TKA elsewhere, which would bolster their overall experience. Finally, and perhaps most importantly, the confounding variables that we could explore in a Level 1/Level 2 registry do not reach a granular level. Although diabetes or rheumatoid arthritis or steroid use is captured to some extent by the AHRQ comorbidity variable, we could not include these separately in a multivariate model. We did examine the operative reports of each of the infected cases in detail, and 14% specifically described a more difficult case related to angular deformity, flexion contracture, or prior surgery. The proportion of the infected cases described as "minimally invasive" (13 of 73 [18%]) or performed with computer navigation (18 of 73 [23%]) may have been higher than the group as a whole, but these data are not routinely captured in the database.

Our large joint registry data set of standardized operative times provided an opportunity to determine whether increased operative time is an independent risk factor for revision resulting from infection after primary TKA. In our multivariate analysis, we did not find significant evidence that increased operative time increased the hazard of revision resulting from infection; a 15-minute increase in operative time increased the hazard of revision resulting from infection by only 15.6% on average ($p = 0.053$; 95% CI, 0.0%–34.1%). Previous studies have provided some evidence of a link between operative time and infection risk [21, 23, 24]. A retrospective analysis carried out by Peersman et al. [23] on 6489 patients who underwent primary TKA analyzed the association between the duration of the surgical procedure and the risk of postoperative infection. They found that a matched control group of TKAs without infections ($n = 236$) had surgery durations of 94 ± 28 minutes, whereas TKAs with infection ($n = 104$) had durations of 127 ± 45 minutes ($p < 0.001$). From the perspective of increased infection risk, the authors suggested that this duration (127 minutes) could be interpreted as the critical duration of surgery. Saleh et al. [27] also found operative duration to be an independent intraoperative risk factor for superficial SSI in total joint arthroplasties with a high association between superficial SSI and deep wound infection. Namba et al. [21] carried out a retrospective review of a prospectively followed cohort of 56,216 primary TKAs recorded in a total joint arthroplasty registry. The incidence of deep SSI was 0.72% (404 of 56,216), virtually identical to the incidence of revision for infection of 0.73% found in our study. In a subanalysis, operative time was a risk factor with a 9% increased risk per 15-minute increment. The time difference between the mean operative time of the infected versus noninfected TKAs (roughly 6 minutes) in our study is substantially different than that of the Peersman et al. study [23], and it is certainly possible that a "threshold time" exists where infection becomes decidedly more likely even if such risk exists on a continuum. Although our study showed a similar relationship between operative time and infection risk as the Namba et al. [21] study, our findings were not significant ($p = 0.053$) once the confounders of age and sex were included. This may be related to our endpoint of revision for infection rather than detection of deep SSI or may be simply the result of the relative infrequency of revision for infection in primary TKAs in our population and the smaller overall numbers in our database.

Our study also found that a five-unit increase in BMI corresponds to a 1.9-minute increase in operative time on average, regardless of sex; operative time is, on average, 10.2 minutes longer for males than females with the same BMI. The relationship between increasing BMI and prolonged operative time has been previously documented [1, 15, 25, 35]. A study of 273 patients undergoing TKA by Liabaud et al. [15] showed a direct linear relationship between BMI and operative time. The authors noted that, on average, for every 1-kg/m^2 increase in BMI, the operative time increases by 0.933 minute [15]. Their study is also in agreement with the present study regarding prolonged operative times in male populations as compared with female populations with the same BMI. We would hypothesize that greater BMI leads to greater difficulties in both exposure and closure that might prolong operative time. Similarly, male populations may have greater extensor mechanism mass complicating exposure, denser bone to cut, or some combination of these and other factors that prolong operative time compared with females. Although other studies have identified increased BMI as a risk factor for postoperative infection after TKA [1, 15, 25, 35], we could not identify it as an independent risk factor for revision secondary to infection in our population. As previously mentioned, this is likely the result of the small number of events in question and perhaps also the result of the event being monitored, ie, revision surgery for infection rather than SSI itself.

Our study also attempted to quantify the association between surgeon procedural volume and the operative time. We noted that the effect of greater volume was surprisingly modest (approximately 5 minutes of operative time) and appeared to plateau after 300 TKAs such that greater volume did not decrease operative time. There are very limited data describing the relationship between surgeon procedure volume and the operative time required for TKA [11]. Most of the studies in the literature have studied the relationship between surgeon procedure volume and the outcomes of TKA [8, 9, 14].

In a meta-analysis carried out by Lau et al. [14], a significant association between low surgeon volume and higher rates of infection, longer procedure time, longer length of stay, higher transfusion rate, and worse patient outcomes was found. King et al. [11] compared the first 100 minimally invasive approach (MIA) TKAs done by a single high-volume arthroplasty surgeon with his previous 50 procedures performed through a standard medial parapatellar approach (MPA). The MIA took significantly longer to perform, on average, than the MPA (86.3 and 78.9 minutes, respectively; $p = 0.01$). Long operative times were noted in the first 25 limbs in the MIA group (mean, 102.5 minutes). The authors concluded that a quadriceps-sparing MIA seems to have a substantial learning curve (50 procedures in the hands of a high-volume arthroplasty surgeon) [11]. In our study, the mean operative time for all surgeons for primary TKA viewed annually was between 86.1 and 87.9 minutes in 2000 to 2003, but between 94 and 98.2 minutes from 2004 to 2009 before dipping to 92 minutes or less after 2010. Thus, the increasing use of "minimally invasive" approaches and computer navigation during the midperiod of this study that increased operative time even for experienced surgeons may account for the relatively modest effect of experience seen here. It may also be that most surgeons in our community perform enough of this common procedure during training that the learning curve has already shortened appreciably for their practice.

After controlling for confounding variables, the effect of operative time on risk of revision for infection is weak as an isolated factor, because infection itself remains a rare event. Increasing BMI and male sex increase operative time but have been found in other studies to increase infection risk independently. Infection after TKA involves a complex interaction of variables involving both host and surgeon, and large populations are required to measure meaningful effects. Until all such potential variables can be used in risk calculation models, surgeons should view older obese males with complex knee problems that may require longer operative times as at higher risk for infection and counsel them appropriately.

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