

Prolonged surgical time increases the odds of complications following total knee arthroplasty

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Background: The aim of this study was to evaluate the influence of operating time on complications and readmission within 30 days of total knee arthroplasty (TKA) and to determine if there were specific time intervals associated with worse outcomes.

Methods: The American College of Surgeons' National Surgical Quality Improvement Program database was used to identify patients 18 years of age and older who underwent TKA between 2006 and 2017, using procedural codes. Patient demographic characteristics, operation length and 30-day major and minor complication and readmission rates were captured. We used multivariable regression to determine if the rates of complications and readmission differed depending on the length of the operation, while adjusting for relevant covariables.

Results: A total of 263 174 patients who underwent TKA were identified from the database. Their mean age was 66.8 (standard deviation 9.7) years. Within 30 days of the index procedure, 5700 patients (2.2%) experienced a major complication, 5185 (2.0%) experienced a minor complication and 7730 (3.1% of 249 746 patients from 2011 to 2017) were readmitted. Mean operation length was 91.7 minutes (range 30–240 min). After adjustment for relevant covariables, an operating time of 90 minutes or more was a significant predictor of major and minor complications as well as readmission. There was no difference in the odds of complications or readmission for operations lasting 30–49, 50–69 or 70–89 minutes ($p > 0.05$).

Conclusion: Our data suggest that operating times of 90 minutes or more may be associated with an increase in the 30-day odds of complications and readmission following TKA. Further studies are needed to confirm our findings and determine the influence of surgical time on outcomes when there is increased case complexity.

Contexte : Cette étude avait pour but d'évaluer l'influence de la durée opératoire sur les taux de complications et de réadmission dans les 30 jours suivant une arthroplastie totale du genou (ATG) et de déterminer si certaines durées étaient associées à des issues défavorables.

Méthodes : Nous avons interrogé la base de données du National Surgical Quality Improvement Program de l'American College of Surgeons pour repérer, à l'aide de codes d'acte, les patients de 18 ans et plus ayant subi une ATG entre 2006 et 2017. Les caractéristiques démographiques des patients, la durée opératoire et les taux de complications mineures et majeures et de réadmission dans les 30 jours suivant l'intervention ont été relevés. Nous nous sommes servis d'une régression logistique multivariée pour déterminer si les taux de complications et de réadmission variaient selon la durée opératoire, tout en tenant compte des covariables pertinentes.

Résultats : Au total, 263 174 patients ayant subi une ATG ont été repérés dans la base de données. L'âge moyen était de 66,8 ans (écart type : 9,7 ans). Dans les 30 jours suivant l'intervention de référence, 5700 patients (2,2 %) ont présenté une complication majeure et 5185 (2,0 %), une complication mineure; 7730 patients (3,1 % des 249 746 patients ayant subi une ATG entre 2011 et 2017) ont été réhospitalisés. La durée opératoire moyenne était de 91,7 minutes (plage 30–240 minutes). Après la prise en compte des covariables pertinentes, une durée opératoire de 90 minutes ou plus était un facteur prédictif significatif de complications mineures ou majeures et de réadmission. Aucune différence n'a été constatée quant à la probabilité de complications ou de réadmission pour les chirurgies durant de 30–49 minutes, de 50–69 minutes et de 70–89 minutes ($p > 0,05$).

Conclusion : Ces données laissent croire qu'une durée opératoire de 90 minutes ou plus peut être associée à une hausse des taux de complications et de réadmission dans les 30 jours suivant une ATG. D'autres études sont nécessaires pour confirmer ces résultats et déterminer l'influence de la durée opératoire sur les issues des patients au cas complexe.

The need for primary total knee arthroplasty (TKA) has grown steadily over the last decade. More than 700 000 TKAs are performed yearly in the United States, and it is projected that demand for TKAs will increase by 673% by 2030.¹ As the number of TKAs being performed increases it is expected that the number of complications will increase as well. Therefore, it is imperative to identify risk factors associated with complications following TKA. Previous studies identified prolonged operating time as a risk factor associated with greater anesthesia-related risks, wound problems and surgical site infections following joint replacement.²⁻⁴ Belmont and colleagues showed that patients with operating times greater than 135 minutes had a significantly higher rate of complications including pulmonary embolism (PE), postoperative sepsis, urinary tract infection (UTI) and deep venous thrombosis (DVT).⁵ Similar studies showed an increase in rates of adverse events such as transfusion, wound dehiscence, sepsis and readmission with prolonged surgical time.^{4,6}

To our knowledge, there have not been any large population-based studies evaluating the effect of operating time on complications using data as recent as 2017 and including only patients undergoing TKA, in an attempt to ascertain an optimal surgery time. The purpose of this study was to examine the American College of Surgeons' National Surgical Quality Improvement Program (NSQIP) database to evaluate (1) how operating time affected 30-day complication and readmission rates following TKA, (2) if operating time was correlated with better or worse outcomes, and (3) how operating times for TKA differed between 2006 and 2017.

METHODS

The NSQIP is a risk-adjusted, validated, outcome-based program collecting data on patients undergoing major surgical procedures. Its database includes information on patient characteristics such as demographics, comorbidities and perioperative variables, as well as 30-day postoperative complications and readmission rates.⁷ Variables are collected prospectively by surgical clinical reviewers for 30 days after surgery even if a patient is discharged from the hospital. The data are internally audited and the disagreement rate is less than 2%.⁸ There are more than 750 participating centres; more than 90% of them are located in the US.⁹

All patients aged 18 years or older who underwent elective primary TKA between 2006 and 2017 were identified and included in this study. Patients were identified using the current procedural terminology (CPT) code 27447 (arthroplasty, knee, condyle and plateau; medial and lateral compartments with or without patella resurfacing). Patients with an operating time of less than 30 minutes or more than 240 minutes were excluded from the study, to eliminate potential coding errors or outliers.

Patient baseline characteristics including age, sex, American Society of Anesthesiologists (ASA) classification, body mass index (BMI), functional and smoking status, preoperative hematocrit and comorbidities including hypertension, diabetes, congestive heart failure (CHF) and chronic obstructive pulmonary disease (COPD) were ascertained. Data on operating time from incision to the completion of all procedure-related activities on the patient and the type of anesthesia (general, epidural or spinal) were collected.

The primary outcome was major complications within 30 days of the initial procedure. These included myocardial infarction (MI), DVT, PE, stroke, septic shock, cardiac arrest, deep surgical site infection (SSI), unplanned reintubation, being on a ventilator for more than 48 hours and acute renal failure. Secondary outcomes included minor complications (superficial SSI, pneumonia, UTI, wound dehiscence and renal insufficiency) and hospital readmission (available in the NSQIP from 2011 to 2017). A readmission consisted of any unplanned readmission to any hospital within 30 days of surgery even if the hospital was not the one where the TKA was performed. The grouping of major and minor complications was based on previous NSQIP literature.^{10,11}

Statistical analysis

Descriptive statistics including means, standard deviations (SDs) and frequencies for all variables of interest were reported. Unadjusted rates of outcomes between groups were evaluated using χ^2 tests. We chose surgical duration categories (30-49, 50-69, 70-89, 90-109, 110-129, 130-149 and ≥ 150 min) a priori after consulting with orthopedic surgeons experienced in performing TKAs. In addition to evaluating the differences between all surgical duration groups, we dichotomized surgical duration ($>$ and $<$ 90 min) to determine whether the cut-off of 90 minutes was significant. We chose the cut-off of 90 minutes after consulting with orthopedic surgeons experienced in this procedure and in accordance with a recent publication about the risk of complications with prolonged surgical time in total hip arthroplasty.¹²

We performed multivariable logistic regression analyses to identify independent predictors of operating time while adjusting for other relevant variables such as comorbidities, age, BMI, ASA class and functional and smoking status. Operating time was primarily evaluated as a categorical variable for the logistic regression analyses to determine if there was a specific time that was associated with better or worse outcomes. In addition, operating time was evaluated as a continuous variable to determine if there was a linear relationship between surgical duration and outcomes. Variables were included in the models on the basis of clinical and statistical significance. Readmission data were included for patients only between 2011 and 2017 as this

information was included in the NSQIP database only after 2010. We performed a sensitivity analysis to determine whether including the surgical year in the model changed the interpretation of the results. The models were checked for multicollinearity using tolerance and variance inflation factors. The fit of each model was evaluated using C-statistics and Hosmer–Lemeshow tests. All statistical analyses were performed using SAS 9.4 (SAS Institute Inc.). The level of significance was set as $p < 0.05$.

RESULTS

A total of 263 174 patients who underwent TKA were identified, with a mean age of 66.8 (SD 9.7) years. Patient baseline and perioperative characteristics are reported in Table 1. The mean operating time was 91.7 minutes (range 30–240 min) with 45% of the cases taking 90 minutes or more. The mean operating time decreased from 121.8 minutes in 2006 to 89.2 minutes in 2017 (Figure 1).

Independent predictors of a longer operation length included higher BMI, male sex, hypertension and dependent functional status. Independent predictors of a shorter operation length included older age, higher preoperative hematocrit, COPD, neuraxial anesthesia and diabetes.

Unadjusted analyses of postoperative complications and the 30-day rate of readmission are summarized in Table 2. A total of 5700 patients (2.2%) had a major complication

and 5185 (2.0%) had a minor complication, and 7730 (3.1%) patients between 2011 and 2017 were readmitted. The unadjusted proportions of major complications, minor complications and readmission were significantly higher for patients whose operating times were 90 minutes or more ($p < 0.001$). Specifically, the unadjusted proportions of DVT, sepsis, deep and superficial SSI, acute renal failure and wound dehiscence were higher for patients whose operating times were 90 minutes or more (Table 3).

After controlling for potential confounders, multi-variable logistic regression analyses showed that operating times of 90–109 minutes increased the odds of major complications by 1.16 (95% confidence interval [CI] 1.08–1.25) and the odds of minor complications by 1.09 (95% CI 1.01–1.18) compared with an operating time of 70–89 minutes. The odds of complications increased further with longer operating times. Compared with an operating time of 70–89 minutes, an operation length of 110–129 minutes increased the odds of major complications by 1.22 (95% CI 1.12–1.34) and the odds of minor complications by 1.12 (95% CI 1.02–1.24), while operating times of 130–149 minutes increased the odds of major complications by 1.30 (95% CI 1.16–1.46) and the odds of minor complications by 1.23 (1.09–1.39). Operating times of 150 minutes or longer increased the odds of major complications by 1.51 (95% CI 1.35–1.68) and the odds of minor complications by 1.44 (95% CI 1.29–1.62). There were no differences in

Table 1. Patient demographic characteristics and comorbidities by operation length

Characteristic	No. (%) of patients;* operating time						
	30–49 min <i>n</i> = 12 188	50–69 min <i>n</i> = 55 255	70–89 min <i>n</i> = 77 150	90–109 min <i>n</i> = 56 136	110–129 min <i>n</i> = 31 474	130–149 min <i>n</i> = 15 554	≥ 150 min <i>n</i> = 15 417
Age, yr, mean ± SD	67.9 ± 9.8	68.1 ± 9.5	67.4 ± 9.5	66.4 ± 9.6	65.6 ± 9.7	65.0 ± 9.8	63.9 ± 9.8
Female	8986 (71.6)	62563 (66.2)	57319 (61.0)	23071 (56.8)	11 667 (53.4)		
BMI, kg/m ² , mean ± SD	32.2 ± 6.6	32.4 ± 6.7	32.8 ± 6.8	33.2 ± 7.1	33.5 ± 7.1	33.7 ± 7.1	33.9 ± 7.3
Hypertension	7827 (64.2)	36 107 (65.4)	50 672 (65.7)	36 964 (65.9)	20 784 (66.0)	10 326 (66.4)	9 941 (64.5)
COPD	479 (3.9)	2065 (3.7)	2720 (3.5)	2017 (3.6)	1060 (3.4)	509 (3.3)	477 (3.1)
CHF	34 (0.3)	132 (0.2)	200 (0.3)	170 (0.3)	98 (0.3)	49 (0.3)	34 (0.2)
Bleeding disorder	239 (2.0)	1174 (2.1)	1681 (2.2)	1289 (2.3)	794 (2.5)	383 (2.5)	332 (2.2)
Steroid use	455 (3.7)	1923 (3.5)	2688 (3.5)	1951 (3.5)	1146 (3.6)	580 (3.7)	544 (3.5)
Smoker	1066 (8.8)	4363 (7.9)	6222 (8.1)	4903 (8.7)	2769 (8.8)	1444 (9.3)	1560 (10.1)
Diabetes	2177 (17.9)	9589 (17.4)	13 967 (18.1)	10 301 (18.4)	5921 (18.8)	2961 (19.0)	2804 (18.2)
General anesthesia	5266 (43.2)	22 306 (40.4)	35 989 (46.7)	28 763 (51.2)	17 362 (55.2)	9094 (58.5)	9573 (62.1)
ASA class							
1	250 (2.1)	1158 (2.1)	1429 (1.9)	1004 (1.8)	563 (1.8)	314 (2.0)	322 (2.1)
2	5797 (47.5)	27 261 (49.3)	38 208 (49.5)	27 392 (48.8)	15 176 (48.2)	7339 (47.2)	7329 (47.5)
3	5906 (48.5)	25 921 (46.9)	36 241 (47.0)	26 832 (47.8)	15 181 (48.2)	7612 (48.9)	7487 (48.6)
4	235 (1.9)	915 (1.7)	1272 (1.6)	908 (1.6)	554 (1.8)	289 (1.9)	279 (1.8)
Dependent functional status	142 (1.1)	1003 (1.1)	1173 (1.3)	642 (1.6)	398 (1.8)		
Preoperative hematocrit, %, mean ± SD	40.8 ± 3.9	40.9 ± 3.9	40.9 ± 4.0	40.9 ± 4.1	40.9 ± 4.1	40.9 ± 4.1	40.9 ± 4.3

ASA = American Society of Anesthesiologists; BMI = body mass index; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; SD = standard deviation.
*Unless indicated otherwise.

the odds of major or minor complications for operating times of 30–49 or 50–69 minutes compared with 70–89 minutes. Multivariable models are presented in Table 4.

The odds of readmission were also significantly related to operating time. Following covariable adjustment, an operating time of 90–109 minutes increased the odds of readmission by 1.10 (95% CI 1.03–1.17), an operating time of 110–129 minutes increased the odds of readmission by 1.17 (95% CI 1.08–1.27), an operating time of 130–149 minutes increased the odds of readmission by 1.28 (95% CI 1.16–1.41)

and an operating time of 150 minutes or longer increased the odds of readmission by 1.34 (95% CI 1.21–1.47) compared with an operating time of 70–89 minutes. There were no differences in the odds of readmission for operating times lasting 30–49 or 50–69 minutes compared with 70–89 minutes ($p > 0.05$).

In terms of specific complications, an operating time of 90 minutes or more was an independent predictor of DVT, deep SSI and wound dehiscence whereas an operating time of 150 minutes or longer was an independent predictor of PE, septic shock, sepsis, superficial SSI, pneumonia and UTI. In the sensitivity analyses, including surgical year in the multivariable models did not significantly change the interpretation of our results (Table 5). When we evaluated operating time as a continuous variable, each 1-minute increase in surgical duration was associated with an increase in major complications (odds ratio [OR] 1.004, 95% CI 1.003–1.005), minor complications (OR 1.002, 95% CI 1.001–1.003) and readmission (OR 1.002, 95% CI 1.001–1.003) (Table 6, Table 7).

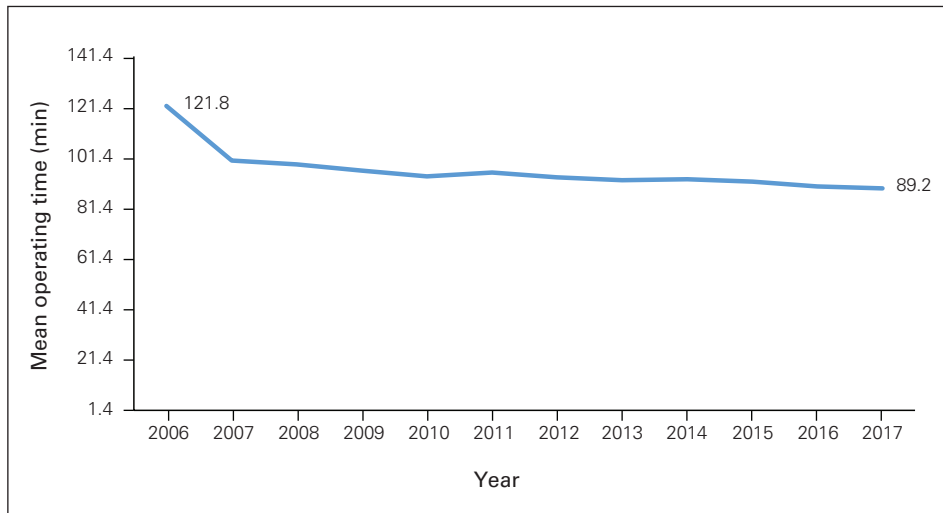


Fig. 1. Mean operating time for total knee arthroplasty between 2006 and 2017.

Table 2. Unadjusted analyses of postoperative complications and 30-day readmission

Outcome	No. (%) of patients; operating time							p value
	30–49 min n = 12 188	50–69 min n = 55 255	70–89 min n = 77 150	90–109 min n = 56 136	110–129 min (n = 31 474)	130–149 min (n = 15 554)	≥ 150 min (n = 15 417)	
Major complications	235 (1.9)	1076 (2.0)	1519 (2.0)	1278 (2.3)	753 (2.4)	395 (2.5)	444 (2.9)	< 0.001*
MI	28 (0.2)	94 (0.2)	154 (0.2)	114 (0.2)	73 (0.2)	35 (0.2)	30 (0.2)	0.53
DVT	81 (0.7)	428 (0.8)	595 (0.8)	517 (0.9)	292 (0.9)	150 (1.0)	162 (1.1)	< 0.001*
PE	70 (0.6)	325 (0.6)	438 (0.6)	326 (0.6)	179 (0.6)	88 (0.6)	111 (0.7)	0.48
Stroke	9 (0.1)	53 (0.1)	57 (0.1)	53 (0.1)	27 (0.1)	13 (0.1)	10 (0.1)	0.75
Septic shock	8 (0.1)	43 (0.1)	38 (0.1)	26 (0.1)	15 (0.1)	5 (0.0)	17 (0.1)	0.015*
Sepsis	17 (0.1)	73 (0.1)	151 (0.2)	117 (0.2)	76 (0.2)	41 (0.3)	67 (0.4)	< 0.001*
Cardiac arrest	9 (0.1)	46 (0.1)	55 (0.1)	44 (0.1)	22 (0.1)	14 (0.1)	12 (0.1)	0.98
Deep SSI	11 (0.1)	53 (0.1)	63 (0.1)	84 (0.2)	56 (0.2)	29 (0.2)	45 (0.3)	< 0.001*
Organ space SSI	13 (0.1)	56 (0.1)	105 (0.1)	108 (0.2)	75 (0.2)	46 (0.3)	45 (0.3)	< 0.001*
Reintubation	23 (0.2)	74 (0.1)	111 (0.1)	78 (0.1)	43 (0.1)	33 (0.2)	29 (0.2)	0.19
Ventilator > 48 h	10 (0.1)	26 (0.1)	53 (0.1)	38 (0.1)	22 (0.1)	13 (0.1)	14 (0.1)	0.45
Acute renal failure	3 (0.0)	9 (0.0)	12 (0.0)	17 (0.0)	11 (0.0)	8 (0.1)	7 (0.1)	0.044*
Minor complications	236 (1.9)	1053 (1.9)	1409 (1.8)	1112 (2.0)	640 (2.0)	344 (2.2)	391 (2.5)	< 0.001*
Superficial SSI	58 (0.5)	291 (0.5)	365 (0.5)	307 (0.6)	210 (0.7)	94 (0.6)	112 (0.7)	0.001*
Pneumonia	47 (0.4)	190 (0.3)	245 (0.3)	199 (0.4)	96 (0.3)	50 (0.3)	64 (0.4)	0.41
UTI	104 (0.9)	467 (0.9)	658 (0.9)	463 (0.8)	238 (0.8)	135 (0.9)	146 (1.0)	0.51
Wound dehiscence	17 (0.1)	82 (0.2)	111 (0.1)	115 (0.2)	85 (0.3)	54 (0.4)	60 (0.4)	< 0.001*
Renal insufficiency	15 (0.1)	53 (0.1)	84 (0.1)	66 (0.1)	43 (0.1)	21 (0.1)	28 (0.2)	0.15
Readmission*	339 (2.9)	1530 (2.9)	2106 (2.9)	1670 (3.2)	1002 (3.4)	538 (3.7)	545 (3.8)	< 0.001*

Note: Analyses were conducted using χ^2 tests. DVT = deep vein thrombosis; MI = myocardial infarction; PE = pulmonary embolism; SSI = surgical site infection; UTI = urinary tract infection.
*Readmission data were available only for 2011–2017.

Table 3. Dichotomized adjusted analyses of postoperative complications and 30-day readmission

Outcome	No. (%) of patients; operating time		p value
	30–89 min n = 148322	≥ 90 min n = 114852	
Major complications	2906 (2.0)	2794 (2.4)	< 0.001
MI	280 (0.2)	248 (0.2)	0.12
DVT	1140 (0.8)	1085 (0.9)	< 0.001
PE	853 (0.6)	684 (0.6)	0.49
Stroke	122 (0.1)	100 (0.1)	0.67
Septic shock	91 (0.1)	61 (0.1)	0.38
Sepsis	247 (0.2)	295 (0.3)	< 0.001
Cardiac arrest	111 (0.1)	91 (0.1)	0.69
Deep SSI	132 (0.1)	209 (0.2)	< 0.001
Organ space SSI	179 (0.1)	269 (0.2)	< 0.001
Reintubation	211 (0.1)	180 (0.2)	0.34
Ventilator > 48 h	89 (0.1)	87 (0.1)	0.12
Acute renal failure	24 (0.0)	43 (0.0)	< 0.001
Minor complications	2776 (1.9)	2409 (2.1)	< 0.001
Superficial SSI	741 (0.5)	696 (0.6)	< 0.001
Pneumonia	492 (0.3)	399 (0.4)	0.49
UTI	1261 (0.9)	950 (0.8)	0.52
Wound dehiscence	217 (0.2)	307 (0.3)	< 0.001
Renal insufficiency	156 (0.1)	154 (0.1)	0.032
Readmission*	4073 (2.9)	3657 (3.4)	< 0.001

DVT = deep vein thrombosis; MI = myocardial infarction; PE = pulmonary embolism; SSI = surgical site infection; UTI = urinary tract infection.
*Readmission data were available only for 2011–2017.

DISCUSSION

To our knowledge, this study is the first to evaluate the effect of specific operating times on 30-day major and minor complications following 263 174 TKA procedures using a national-based validated surgical outcome database. Our findings indicate that an operating time of 90 minutes or more is independently associated with a significant increase in the rates of major and minor complications and readmission following TKA. These data also suggest that there was a significant decrease in the operating time for TKA between 2006 and 2017. This was probably related to improved efficiency in the operating room and changing models of care over time.

These results are in concordance with previous literature. Bohl and colleagues⁶ examined the NSQIP database between 2006 and 2013 to examine the effect of operating time on adverse events following both THA and TKA in 165 474 patients. They concluded that each increase of 15 minutes in operating time increased the risk of anemia requiring transfusion, wound dehiscence, renal insufficiency, sepsis, SSI, UTI and readmission to hospital. Similarly, Duchman and colleagues⁴ determined the rate of complications in 99 444 patients following joint replacement using NSQIP data between 2011 and 2013, showing an increase in overall complications and specifically wound problems in patients with an operating time of 120 minutes

Table 4. Results of multivariable logistic regression analyses

Outcome and operating time	Odds ratio (95% CI)	p value
Major complications		
30–49 min	0.98 (0.86–1.13)	0.79
50–69 min	0.99 (0.91–1.07)	0.10
70–89 min	Ref.	—
90–109 min	1.16 (1.08–1.25)	0.006
110–129 min	1.22 (1.12–1.34)	0.008
130–149 min	1.30 (1.16–1.46)	< 0.001
≥ 150 min	1.51 (1.35–1.68)	< 0.001
Minor complications		
30–49 min	1.05 (0.91–1.21)	0.86
50–69 min	1.04 (0.96–1.13)	0.24
70–89 min	Ref.	—
90–109 min	1.09 (1.01–1.18)	0.009
110–129 min	1.12 (1.02–1.24)	0.008
130–149 min	1.23 (1.09–1.39)	0.002
≥ 150 min	1.44 (1.29–1.62)	< 0.001
Readmission*		
30–49 min	1.00 (0.89–1.13)	0.28
50–69 min	1.01 (0.94–1.08)	0.24
70–89 min	Ref.	—
90–109 min	1.10 (1.03–1.17)	0.003
110–129 min	1.17 (1.08–1.27)	< 0.001
130–149 min	1.28 (1.16–1.41)	< 0.001
≥ 150 min	1.34 (1.21–1.47)	< 0.001

Note: Each model controlled for age, sex, body mass index, chronic obstructive pulmonary disease, congestive heart failure, American Society of Anesthesiologists class, preoperative hematocrit, functional status, smoking status, diabetes, hypertension, steroid use, bleeding disorder and anesthesia type. CI = confidence interval; Ref. = reference.
*Readmission data were available only for 2011–2017.

or more. Finally, Belmont and colleagues⁵ used NSQIP data to identify an operation length of greater than 135 minutes as an independent predictor of complications, mortality and length of stay following TKA. However, these authors did not adjust for variables such as functional status, preoperative hematocrit and anesthesia type, which this study has shown can independently influence operation length. The current study evaluated the NSQIP database between 2006 and 2017 to evaluate the effect of operating time on the rates of complications in 263 174 patients following TKA. These results indicate that an operating time of 90 minutes or more is a risk factor for both major and minor complications and readmission.

Although there are some similarities between the present study and previous studies, this study is an important addition to the current literature for the following reasons. First, we specifically analyzed data for patients who underwent TKA, rather than evaluating all joint replacements. This is important because it is probable that the effect of operating time and the optimal surgical duration may differ between the THA and TKA groups. Song and colleagues¹³ showed that a prolonged operating time was a risk factor for increased length of stay following THA but not TKA.

Table 5. Results of multivariable regression sensitivity analyses including admission year as a covariable

Outcome and operating time	Odds ratio (95% CI)	p value
Major complications		
30–49 min	1.00 (0.87–1.15)	0.89
50–69 min	0.99 (0.92–1.08)	0.15
70–89 min	Ref.	—
90–109 min	1.15 (1.07–1.24)	0.016
110–129 min	1.21 (1.11–1.32)	0.015
130–149 min	1.29 (1.15–1.44)	< 0.001
≥ 150 min	1.49 (1.34–1.66)	< 0.001
Minor complications		
30–49 min	1.07 (0.93–1.23)	0.34
50–69 min	1.05 (0.96–1.13)	0.71
70–89 min	Ref.	—
90–109 min	1.08 (1.00–1.17)	0.018
110–129 min	1.11 (1.01–1.22)	0.014
130–149 min	1.21 (1.08–1.22)	0.007
≥ 150 min	1.42 (1.27–1.59)	< 0.001
Readmission*		
30–49 min	1.00 (0.89–1.12)	0.43
50–69 min	1.01 (0.94–1.08)	0.12
70–89 min	Ref.	—
90–109 min	1.10 (1.03–1.18)	0.015
110–129 min	1.28 (1.09–1.27)	< 0.001
130–149 min	1.29 (1.17–1.42)	< 0.001
≥ 150 min	1.35 (1.22–1.48)	< 0.001

Note: Each model controlled for age, sex, body mass index, chronic obstructive pulmonary disease, congestive heart failure, American Society of Anesthesiologists class, preoperative hematocrit, functional status, smoking status, diabetes, hypertension, steroid use, bleeding disorder, anesthesia type and admission year. CI = confidence interval; Ref. = reference.
*Readmission data were available only for 2011–2017.

Table 6. Multivariable analysis of operation length as a continuous variable

Outcome	Odds ratio (95% CI)	p value
Major complications		
MI	1.003 (1.000–1.006)	0.032
DVT	1.004 (1.002–1.005)	< 0.001
PE	1.002 (1.001–1.004)	0.004
Stroke	1.001 (0.996–1.005)	0.79
Septic shock	1.002 (0.997–1.007)	0.44
Sepsis	1.009 (1.006–1.011)	< 0.001
Cardiac arrest	1.001 (0.996–1.005)	0.69
Deep SSI	1.009 (1.006–1.011)	< 0.001
Organ space SSI	1.007 (1.005–1.010)	< 0.001
Reintubation	1.002 (0.999–1.005)	0.16
Ventilator > 48 h	1.004 (1.000–1.009)	0.06
Acute renal failure	1.008 (1.001–1.014)	0.017
Minor complications		
Superficial SSI	1.002 (1.001–1.003)	< 0.001
Pneumonia	1.001 (0.999–1.003)	0.43
UTI	1.002 (1.000–1.003)	0.023
Wound dehiscence	1.008 (1.006–1.011)	< 0.001
Renal insufficiency	1.004 (1.000–1.007)	0.035
Readmission	1.002 (1.001–1.003)	< 0.001

Note: This analysis controlled for all variables in Table 1. DVT = deep vein thrombosis; MI = myocardial infarction; PE = pulmonary embolism; SSI = surgical site infection; UTI = urinary tract infection.

Table 7. Multivariable analysis of operation length as a continuous variable, including admission year as a covariable

Outcome	Odds ratio (95%CI)	p value
Major complications		
MI	1.003 (1.000–1.006)	0.035
DVT	1.003 (1.002–1.005)	< 0.001
PE	1.002 (1.000–1.004)	0.012
Stroke	1.001 (0.996–1.005)	0.80
Septic shock	1.002 (0.997–1.007)	0.54
Sepsis	1.008 (1.006–1.011)	< 0.001
Cardiac arrest	1.001 (0.996–1.005)	0.75
Deep SSI	1.008 (1.005–1.011)	< 0.01
Organ space SSI	1.008 (1.005–1.010)	< 0.001
Reintubation	1.002 (0.999–1.005)	0.16
Ventilator > 48 h	1.004 (1.000–1.009)	0.07
Acute renal failure	1.008 (1.001–1.014)	0.018
Minor complications		
Superficial SSI	1.002 (1.001–1.003)	< 0.001
Pneumonia	1.001 (0.999–1.003)	0.45
UTI	1.001 (1.000–1.003)	0.009
Wound dehiscence	1.008 (1.006–1.011)	< 0.001
Renal insufficiency	1.003 (1.000–1.007)	0.048
Readmission	1.003 (1.002–1.004)	< 0.001

Note: This analysis controlled for all variables in Table 1 and admission year. DVT = deep vein thrombosis; MI = myocardial infarction; PE = pulmonary embolism; SSI = surgical site infection; UTI = urinary tract infection.

Second, the primary aim of this study was to determine if there was a specific operating time that was associated with better or worse outcomes. Our data show that complication rates are relatively low and similar with operating times lower than 90 minutes. However, there was a significant increase in both major and minor complications (specifically deep SSI, DVT and wound dehiscence) and readmission for operating times of 90 minutes or more. Third, unlike previous studies, this study examined patients undergoing TKA between 2006 and 2017, therefore increasing the power of the analyses and reflecting more recent practice. Finally, the current study’s large sample size allowed vigorous statistical analyses, including analysis of variables that previous studies did not consider. For example, Belmont and colleagues⁵ did not adjust for functional status, preoperative hematocrit or anesthesia type. In addition, the authors of the previously published studies did not perform sensitivity analyses to examine the robustness of their results.

Limitations

There are a few limitations to this study that are largely related to its retrospective design, including the potential for selection bias and the possibility of a type II error due to the low incidence of complications following TKA. To minimize the chance of a type II error, for our primary outcome we grouped all major complications as previously described in other studies using NSQIP data for patients who had undergone TKA.¹¹ Another limitation is that morbidity and mortality outcomes were limited to 30 days postoperatively,

which meant that we were unable to report on long-term outcomes as well as implant survivorship data. In addition, this follow-up length may be too short to be conclusive with respect to complications related to infection. Although the NSQIP is highly regulated and has high levels of agreement with review of medical records, there is always the possibility of coding errors. Moreover, because of the administrative nature of the data, some relevant variables are not included in the NSQIP database such as annual volume of procedures by institution or surgeon, which have previously been shown to affect the rate of complications and readmissions.^{14,15} In addition, the NSQIP database does not provide information about the patient's degree of arthritis or deformity, antibiotics, case complexity, soft tissue compromise, intraoperative issues (such as intraoperative fracture, instability and malalignment), presence of previous hardware and other confounding variables that may influence operating time or complication risk. Moreover, although patients who present to a NSQIP hospital and receive follow-up care at a non-NSQIP hospital are included in the analysis (and their follow-up care is recorded), patients who present initially to a non-NSQIP hospital are missing from the database. The accurate, regularly audited NSQIP database, with its large sample size, provides a useful source of data with which to measure outcomes following TKA.

Finally, it is possible that some of the variables we identified to influence operation length, such as hypertension, functional status and COPD, were only significant because of our large sample size. However, we believe our results concerning predictors of operation length are important to acknowledge and that certain comorbidities do have the potential to influence operation length. For these reasons, this study can serve as hypothesis generating for future research in this area.

CONCLUSION

In this study using a multicentre database, an operating time of 90 minutes or more may be associated with an increase in complications including deep SSI, DVT and wound dehiscence as well as readmission following TKA. However, we believe that certain comorbidities and patient characteristics do have the potential to influence operation length. Therefore, while our data are in concordance with previous studies, prospective clinical data are required to confirm these findings and determine the role of surgical time when there is increased case complexity.

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