



Original Research

Preoperative Predictors of Same-Day Discharge After Total Knee Arthroplasty

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ABSTRACT

Background: In January 2020, The Centers for Medicare and Medicaid Services approved total knee arthroplasty (TKA) to be performed in ambulatory surgery centers (ASCs). This study aims to develop a predictive model for targeting appropriate patients for ASC-based TKA.

Methods: A retrospective review of 2266 patients (205 same-day discharge [SDD; 9.0%] and 2061 one-day length of stay [91.0%]) undergoing TKA at a regional medical center between July 2016 and September 2020 was conducted. Multiple logistic regression was used to evaluate predictors of SDD, as these patients represent those most likely to safely undergo TKA in an ASC.

Results: Controlling for other demographics and comorbidities, patients with the following characteristics were at reduced odds of SDD: increased age (odds ratio [OR] = 0.935, $P < .001$), body mass index ≥ 35 (OR = 0.491, $P = .002$), female (OR = 0.535, $P < .001$), nonwhite race (OR = 0.456, $P = .003$), primary hypertension (OR = 0.710, $P = .032$), ≥ 3 comorbidities (OR = 0.507, $P = .002$), American Society of Anesthesiologists score ≥ 3 (OR = 0.378, $P < .001$). The model was deemed to be of adequate fit using the Hosmer and Lemeshow test ($\chi^2 = 12.437$, $P = .112$), and the area under the curve was found to be 0.773 indicating acceptable discrimination.

Conclusion: For patients undergoing primary TKA, increased age, body mass index ≥ 35 , female gender, nonwhite race, primary hypertension, ≥ 3 comorbidities, and American Society of Anesthesiologists score ≥ 3 decrease the likelihood of SDD. A predictive model based on readily available patient presentation and comorbidity characteristics may aid surgeons in identifying patients that are candidates for SDD or ASC-based TKA.

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Introduction

Total knee arthroplasty (TKA) is a commonly performed intervention for end-stage osteoarthritis that is associated with significant improvements in pain, function, and health-related quality of life [1–3]. As the population continues to age, demand for TKA is expected to increase and is projected to reach over 1.5 million cases performed annually by 2050 [4]. Over the last 4 decades, advancements in implant designs, improvement in surgical

techniques and instrumentation, and development of rapid recovery protocols have significantly contributed to reducing the length of stay (LOS) and recovery time after TKA [5,6]. In 2018, The Centers for Medicare and Medicaid Services removed TKA from its inpatient-only list, allowing medically and socially optimized patients to discharge home on the same day or next day after TKA [7,8]. Building on the removal of TKA from the inpatient-only list, Centers for Medicare and Medicaid Services has approved the performance of TKA in ambulatory surgery centers (ASCs) as of January 1, 2020.

To facilitate a safe transition to ambulatory TKA, arthroplasty surgeons can build upon their experience with same-day discharges (SDDs) of TKA patients in the hospital setting to identify the best candidates for ASC-based TKA. Evidence from prior studies shows that younger patients with a lower body mass index (BMI)

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and fewer comorbidities are more appropriate candidates for SDD or ASC-based TKA [9,10]. Besides careful patient selection, standardized perioperative protocols, multidisciplinary care coordination, and discharge planning are other important aspects of successful SDD [5,10–12]. Certain factors such as increased age, higher BMI, female gender, history of cardiovascular disease, chronic obstructive pulmonary disorder (COPD), chronic renal or hepatic failure, morbid obesity, insulin-dependent diabetes mellitus, American Society of Anesthesiologists (ASA) score of 3 and higher, and being in a functional dependent state have been shown to increase LOS after TKA, making such candidates inappropriate for SDD [13–18].

In alignment with prior studies, we hypothesize that SDD patients will differ significantly in demographics and comorbidity burden from those requiring an overnight stay after TKA and that these factors can be used to generate a model for predicting which patients will be discharged on the day of surgery. This study aims to create a predictive model for guiding SDD decisions and preoperatively identifying patients that are candidates for ASC-based TKA using readily available patient demographics and comorbidity data. While previous studies have evaluated risk factors that may guide selection of appropriate SDD patients, fewer have combined these factors to develop and test predictive models that may be used in practice. Of the models currently available, significant variability in their complexity and use of factors not readily known to surgeons in the preoperative clinic setting limit their utility. If successful, this will demonstrate the feasibility of developing institution-specific predictive models that may be used to aid in patient selection as surgeons transition from traditional inpatient facilities, such as our own, to the ambulatory setting.

Material and methods

After exempt determination from the Institutional Clinical Research Committee, a retrospective review of 2266 patients undergoing elective unilateral primary TKA at a regional medical center between July 2016 and September 2020 was conducted. Only patients discharged on the day of surgery (SDD) or after one midnight in the hospital (1-day LOS) were included. This population was selected to limit the analysis to patients who were potential candidates for SDD based on clinical presentation and mitigate the impact of payer inpatient stay requirements on discharge timing. Only surgeries beginning before 11:00 a.m. were included to limit the influence of start time on the rate of successful SDD. Surgeries for all payers were included. The study period was selected to reflect our early experience beginning to perform SDD TKA in the hospital setting, as our first cases were performed in the summer of 2016. The selection criteria for SDD TJA patients were as follows: younger than 75 years of age, BMI under 35 kg/m², no sleep apnea, no insulin-dependent diabetes, no significant cardiac conditions or a recent cardiac procedure, no preoperative anemia, no history of urinary retention or benign prostatic hypertrophy, and deep vein thrombosis prophylaxis using a medication other than Coumadin. These criteria were used as general institutional guidelines, with the ultimate decision for SDD made by the surgeon in consultation with the patient. Patients who met the selection criteria for planned SDD were preoperatively counseled in the orthopedic clinic to allow adequate time to prepare for SDD. Planned SDD surgeries were performed as the first or second surgical case of the day whenever possible. Data were extracted from the electronic health record, including age, race, sex, BMI, and the presence or absence of the following comorbidities coded in the electronic health record at the time of surgery: diabetes mellitus (type 1 or 2), COPD, atrial fibrillation (AFIB), congestive heart failure (CHF), coronary artery disease (CAD), end-stage renal disease or chronic

kidney disease, gastroesophageal reflux disease (GERD), anxiety or depression, and primary hypertension (HTN). These comorbidities were selected for inclusion based on previous literature demonstrating their association with increased complications and LOS after TJA [19–30]. A full list of International Classification of Disease 10th Edition codes used to identify the various comorbidities is included in Appendix A. Multiple logistic regression was used to develop the predictive model using variables that were statistically significant at the $P < .200$ level on univariate analysis. Forward conditional regression was performed to limit independent variable inclusion to only significant predictors that added to overall model fit. Model performance was assessed based on its discriminatory value using the area under the curve (AUC) of the receiver operating characteristics curve (ROC). All statistical analyses were performed using SPSS version 26 (IBM, Armonk, NY); statistical significance was defined as $P < .05$.

Results

Of the 2266 patients included in the study, 205 (9.0%) were discharged on the day of surgery. During the study period, 85% of attempted SDD TKA were successful, with inability to void, nausea, and hypotension being the most common reasons for failure to discharge. Overall, patients had an average age of 65.8 ± 8.5 years, BMI of 31.9 ± 5.6 kg/m², were 53.9% female, 82.0% white, and 68.5% were married or had a life partner. Patients discharged on the day of surgery were significantly younger, had lower BMIs, were less likely to be female, and more likely to be white than patients with 1-day LOS. No significant differences between SDD and non-SDD patients were observed for rates of married or life partner, COPD, or CHF (Table 1). SDD patients were significantly less likely to have 5 of the 9 comorbidities studied. These included diabetes mellitus (SDD: 9.3% vs 1-day LOS: 20.6%, $P < .001$), AFIB (SDD: 0.5% vs 1-day LOS: 6.5%, $P < .001$), CAD (SDD: 5.9% vs 1-day LOS: 10.4%, $P = .039$), GERD (SDD: 22.0% vs 1-day LOS: 35.4%, $P < .001$), and primary HTN (SDD: 43.9% vs 1-day LOS: 62.4%, $P < .001$). SDD patients also demonstrated lower cumulative numbers of comorbidities (≥ 3 comorbidities in 13.2% of SDD vs 33.0% of 1-day LOS patients, $P < .001$). Overall, 39.8% of patients had an ASA score ≥ 3 , and SDD patients were less likely to have an ASA ≥ 3 (SDD: 14.6% vs 1-day LOS: 42.3%, $P < .001$). The overall average length of stay (ALOS) for the patient population was 29.2 ± 5.9 hours, with SDD patients having an ALOS of 11.9 ± 1.5 hours and 1-day LOS patients having an ALOS of 30.9 ± 2.2 hours ($P < .001$). Rates of 30-day return to the operating room were similar between groups, occurring in 0.5% of cases.

Using forward conditional logistic regression, age, BMI ≥ 35 , nonwhite race, female gender, primary HTN, ≥ 3 comorbidities, and ASA ≥ 3 were included in the final model. The following variables were eliminated during the conditional logistic regression process, as they did not significantly improve model performance: diabetes mellitus, AFIB, CAD, end-stage renal disease or chronic kidney disease, GERD, anxiety, or depression. Controlling for other demographics and comorbidities, patients with the following characteristics were at reduced odds of SDD: increased age (OR = 0.935, $P < .001$), BMI ≥ 35 (OR = 0.491, $P = .002$), female (OR = 0.535, $P < .001$), nonwhite race (OR = 0.456, $P = .003$), primary hypertension (OR = 0.710, $P = .032$), ≥ 3 comorbidities (OR = 0.507, $P = .002$), ASA ≥ 3 (OR = 0.378, $P < .001$) (Table 2). The discriminatory ability of the model was assessed by the AUC of the receiver operating characteristic curve (ROC). The model was deemed to be of adequate fit using the Hosmer and Lemeshow test ($\chi^2 = 12.437$, $P = .112$), and the AUC was found to be 0.773 (95% CI: 0.744–0.802) indicating

acceptable discrimination (Fig. 1). The model equation for calculating the probability of SDD is presented below:

$$p = \frac{1}{1 + e^{-(3.123 - .067_{\text{age}} - .712_{\text{BMI} \geq 35} - .785_{\text{Non-White Race}} - .625_{\text{Female}} - .343_{\text{HTN}} - .679_{\geq 3 \text{ comorb.}} - .972_{\text{ASA} \geq 3})}}$$

Discussion

Our model presents a potentially useful tool for aiding surgeon identification of patients likely to qualify for SDD. Based on our results, arthroplasty surgeons should consider younger, white, male, patients with BMI <35, no primary HTN, and lower overall comorbidity burden (<3 comorbidities and ASA <3) as primary targets for same day discharge or ASC-based TKA. Extra caution and perioperative clinical support should be employed when considering same day discharge or the ambulatory setting for older, nonwhite, female patients with primary hypertension and multiple comorbidities. Our results provide immediate clinical utility as a ‘red flag’ for targeting same day discharge TKA patients in daily practice, and may be translated to app or electronic medical record–based tools to produce a patient-specific probability of successful same day discharge to inform clinician decisions regarding the optimal site of care.

TKA can be effectively and safely performed in a subset of patients in the ambulatory setting or with hospital-based SDD [8–10,31]. A variety of approaches to identifying predictors of SDD following TKA have been described [18,32,33]. However, given the variability in statistical methodologies (ie, univariate analysis, multivariate linear regression, multivariate logistic regression), types of predictors included (ie, preoperative comorbidities, perioperative factors, illness rating systems, socioeconomic status, and so on), data sets (ie, administrative databases, national registries, institution-specific data) and confounding proliferation of rapid recovery protocols, synthesis and application of the current

literature to address the specific question of which patients are more likely to successfully discharge on the day of TKA, either in the

ambulatory setting or hospital remains challenging.

A retrospective review of patients undergoing primary TKA between 2011 and 2016 using National Surgical Quality Improvement Program (NSQIP) found that dependent functional status, preoperative comorbidities, and postoperative complications were associated with a LOS greater than 24 hours after TKA, while male gender, spinal anesthesia, and monitored anesthesia care were protective against LOS greater than 24 hours [34]. In a prospective cohort study of 4509 patients who underwent TKA across 4 facilities in a single health-care system, Piuze et al. [17] analyzed patient-related risk factors and compared them with the procedure or structural factors to assess predictors of LOS after TKA. They found that male sex, decreased age, lower BMI, lower Charlson Comorbidity Index, and higher Veterans RAND 12 item Health Survey Mental Component Summary Score were significant predictors of shorter LOS after adjusting for patient characteristics and procedure or structural risk factors. After adding procedure or structural-related risk factors such as hospital site, surgeon, implant type, start time and day of the procedure; the model used by the authors showed a notable improvement in predicting LOS after TKA. While these results provide insights into non-patient related predictive factors, such factors are difficult to incorporate into clinical decision support models and challenging to modify, therefore limiting applicability when selecting patients for ambulatory TKA.

Courtney et al. [33] reviewed a consecutive series of 1012 patients who underwent primary total hip and knee arthroplasties at a single institution to identify risk factors associated with

Table 1
Patient demographics, comorbidities, and perioperative outcomes.

Variable	Total (N = 2266)	One-day LOS (N = 2061)	Same-day discharge (N = 205)	P value
Demographics				
Age, Avg. Yrs.	65.8 ± 8.5	66.3 ± 8.4	61.6 ± 7.5	<0.001
BMI, Avg. kg/m ²	31.9 ± 5.6	32.1 ± 5.7	29.9 ± 4.5	<0.001
BMI ≤35, N (%)	660 (29.1)	631 (30.6)	29 (14.1)	<0.001
Female, N (%)	1221 (53.9)	1138 (55.2)	83 (40.5)	<0.001
White race, N (%)	1859 (82.0)	1672 (81.1)	187 (91.2)	<0.001
Married or life partner, N (%)	1553 (68.5)	1416 (68.7)	137 (66.8)	0.581
Comorbidities, N (%)				
Diabetes mellitus	444 (19.6)	425 (20.6)	19 (9.3)	<0.001
COPD	83 (3.7)	78 (3.8)	5 (2.4)	0.328
AFIB	135 (6.0)	134 (6.5)	1 (0.5)	<0.001
CHF	32 (1.4)	31 (1.5)	1 (0.5)	0.356 ^a
CAD	226 (10.0)	214 (10.4)	12 (5.9)	0.039
ESRD or CKD	139 (6.1)	131 (6.4)	8 (3.9)	0.163
GERD	775 (34.2)	730 (35.4)	45 (22.0)	<0.001
Anxiety or depression	515 (22.7)	477 (23.1)	38 (18.5)	0.133
Primary HTN	1377 (60.8)	1287 (62.4)	90 (43.9)	<0.001
≥3 Comorbidities	708 (31.2)	681 (33.0)	27 (13.2)	<0.001
ASA Score ≥3	901 (39.8)	871 (42.3)	30 (14.6)	<0.001
Perioperative outcomes				
LOS, Avg. Hr.	29.2 ± 5.9	30.9 ± 2.2	11.9 ± 1.5	<0.001
30-Day return to OR	11 (0.5)	9 (0.4)	2 (1.0)	0.262 ^a

ASA, American Society of Anesthesiologists; BMI, body mass index; CAD, coronary artery disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ESRD or CKD, end-stage renal disease or chronic kidney disease; GERD, gastroesophageal reflux disease; HTN, hypertension; LOS, length of stay. P values <0.05 in bold.

^a Fisher's Exact Test.

Table 2
Forward conditional logistic regression: predictors of same-day discharge.

Variable	β	Odds ratio	95% CI	P value
Age	-.067	0.935	0.918-0.953	<.001
BMI ≥ 35	-.712	0.491	0.316-0.763	.002
Female gender	-.625	0.535	0.393-0.728	<.001
Nonwhite race	-.785	0.456	0.273-0.763	.003
Primary HTN	-.343	0.710	0.519-0.970	.032
≥ 3 Comorbidities	-.679	0.507	0.326-0.787	.002
ASA ≥ 3	-.972	0.378	0.245-0.584	<.001

ASA, American Society of Anesthesiologists; BMI, body mass index (kg/m²); HTN, hypertension. P values <0.05 in bold.

postoperative complications and identify who should not be considered for either outpatient or short-stay total joint arthroplasty (TJA). In their analysis, they compared patients who experienced late complications, defined as a complication after 24 hours postoperatively, to patients without any complications and identified COPD (OR = 4.16), CHF (OR = 9.71), CAD (OR = 2.80), and cirrhosis (OR = 8.43) as independent risk factors for developing late complications. The authors then used a stepwise, multiple logistic regression to generate a 6-point risk score using the aforementioned independent variables to identify the ideal patients for outpatient or short stay TJA. With the AUC of 0.738, deeming their model a good fit, they concluded that patients with COPD, CHF, CAD, and cirrhosis should not undergo short stay or outpatient TJA. Alternatively, Sher et al. [18] examined the 2011 to 2014 NSQIP database to identify characteristics associated with same-day discharge post-TJA in 120,847 patients. Multivariate analysis identified age >80 (OR = 4.16, P = .001), smoking (OR = 1.42, P < .05), bleeding disorders (OR = 2.56, P = .01), ASA score 3 or 4 (OR = 1.42, P < .05), and severe adverse event predischarge (OR 13.13, P < .0001) as independent predictors for adverse events or readmissions in this population. Although the results from these studies consist of both hip and knee arthroplasty patients, they provide complementary tools for evaluating the risk of late complications, which should be considered in addition to the LOS model presented in our study. Our current study is underpowered to assess the

relatively infrequent occurrence of failed SDD, which occurred in 15% of our attempts. Given the multitude of clinical and operational factors that can lead to failed SDD, and the significantly negative impact it can have on both facility operations and patient experience, further evaluation of this outcome is required. The development of predictive models for preoperatively identifying this population requires future investigation across both the hospital and ambulatory settings.

In an alternative example of a comprehensive predictive risk model, Meneghini et al. [32] conducted a retrospective review of 1120 consecutive primary TJA patients by a single surgeon to develop and assess the predictive ability of medically based risk assessment scores in selecting patients for outpatient and short-stay surgery. They developed the Outpatient Arthroplasty Risk Assessment (OARA) score based on a comprehensive review of systems to identify candidates for SDD or next day discharge and found that OARA score had a predictive value of 81.6% for SDD when compared to the positive predictive value of 56.4% of ASA score and 70.3% for Charlson Comorbidity Index. While the authors concluded that OARA risk score has more precise predictive ability for SDD than ASA score and Charlson Comorbidity Index, the complexity of obtaining an accurate score, based on the required input of variables from a distinct clinical system makes such model challenging to apply using readily available demographic and comorbidity data in daily practice.

Gronbeck et al. [35] queried NSQIP database to identify Medicare aged patients (age ≥ 65 years) who underwent primary TKA between 2006 and 2015 to establish a risk-stratifying nomogram to aid in determining the need of inpatient status in Medicare patients. Their analysis of over 87,000 patients classified age >80 years, simultaneous bilateral TKA, dependent functional status, metastatic cancer, and female gender as greatest determinants of inpatient stay with their predictive model exhibiting an AUC of 0.66. More recently, Moore et al. [36] retrospectively reviewed 325 consecutive patients within a single hospital system who underwent unilateral primary TKAs to identify factors associated with hospital LOS for SDD and inpatient TKA defined by Medicare's 2-midnight rule. Using multivariate logistic regression, their study found that lower BMI (OR = 0.92) and fewer allergies (OR = 0.66) were independently associated with SDD while age (OR = 0.96), BMI (OR = 0.93), surgery start time (OR = 0.80), and Risk Assessment and Prediction Tool (RAPT) score (OR = 1.2) were independently associated with inpatient discharge after the second midnight. RAPT was originally developed to predict postoperative rehabilitation requirement but has been well described in predicting hospital LOS [37,38]. The authors utilized the predictive ability of RAPT to compare their results by constructing ROC curves and calculating the AUC to assess predictive performance of their multivariate models. They reported that the SDD model (AUC: 0.73 vs 0.52; P < .01) and inpatient model (AUC: 0.74 vs 0.62; P < .01) outperformed the RAPT score alone, validating their results.

In comparison to these studies, our model's AUC of 0.773 suggests its discriminatory ability compares favorably to other patient selection tools. A specific strength of our model is that we were able to predict which patients would be discharged on the day of surgery when compared only to patients requiring a 1-day LOS, rather than the broader population of patients undergoing TKA with multi-night LOS. This holds significant practical application, as the model may be useful for resource allocation decisions within the ASC setting, such as preoperatively projecting which patients will require 23-hour stays. Another strength of our model is its specific focus on TKA patients, as other risk stratification techniques have been developed from combined THA and TKA populations. Further, our model's simplicity and reliance on commonly collected preoperative comorbidity data allows for rapid implementation into

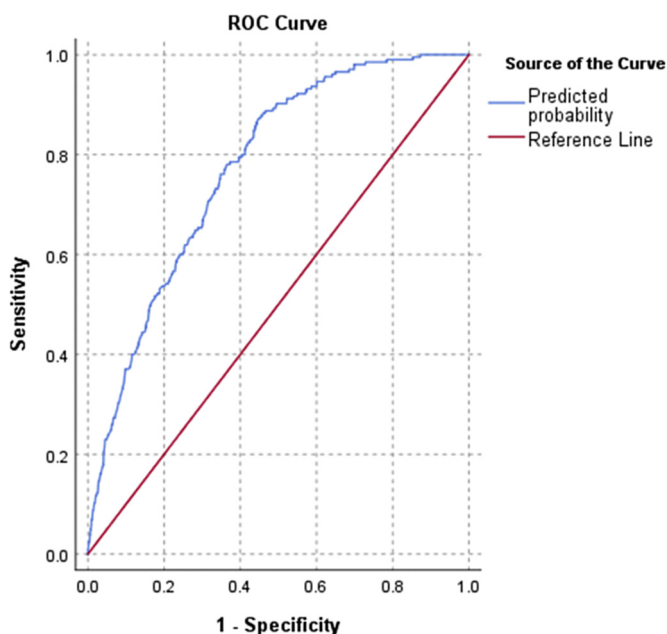


Figure 1. ROC curve analysis of multivariate model predicting same day discharge. Area under the curve (AUC): 0.773, 95% CI: 0.744-0.802.

clinical practice and prospective validation. Despite these strengths, our model should be considered as a supplement to, not a replacement for, patient-specific selection for ambulatory TKA based on provider judgment. While our AUC of 0.773 implies acceptable discriminatory ability, the 22.7% probability of discordance between predicted and actual SDD highlights the complexity of factors influencing successful SDD that must be evaluated by arthroplasty surgeons when selecting patients for ASC-based TKA.

As a retrospective, observational study our results are exposed to selection bias. This must be especially noted when considering that the predictive model produced is influenced by current selection criteria for SDD used at our institution. Second, only 9.0% of patients in this study underwent SDD TKA, and the cohorts compared were highly unbalanced in sample size. Despite these limitations, we suggest this study provides as framework for evaluating the relationship between comorbidities and SDD that can be replicated by other surgeons with historically inpatient practices who are transitioning to the ASC setting. Third, our methodology relied on the use of coded medical comorbidity data from hospital billing systems, which have been shown to have limited quality and fidelity. Fourth, our model did not specifically examine predictors of postoperative complications, although a low (<1%) and a nonsignificant difference in return to OR between SDD and 1-day LOS patients provides adequate control for adverse outcomes. Fifth, while our study included all SDD TKA patients regardless of payer, the removal of TKA from the Medicare inpatient only list on January 1, 2018, may confound our results as Medicare patients were not eligible for SDD during the first 18 months of the study period. Finally, due to our retrospective design we were unable to assess the influence of other important factors such as social support, socioeconomic status, physical function, and the use of assistive devices on successful SDD. Since the close of this study our institution has received funding to evaluate the impact of these factors on outcomes in high-risk patients, which will be the focus of our future research.

Conclusions

For patients undergoing primary TKA, increased age, BMI ≥ 35 , female gender, nonwhite race, primary hypertension, ≥ 3 comorbidities, and ASA ≥ 3 decrease the likelihood of same day discharge. A predictive model based on readily available patient presentation and comorbidity characteristics may aid surgeons in identifying patients that are candidates for same-day discharge or ASC-based TKA.

Conflict of interests

The authors declare there are no conflicts of interest.

Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.artd.2020.12.006>.

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