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Preoperative Body Mass Index and Physical Function Are Associated with Length of Stay and Facility Discharge After Total Knee Arthroplasty

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Abstract

BACKGROUND—Hospital length of stay (LOS) and facility discharge are primary drivers of the cost of total knee arthroplasty (TKA). The purpose of this study was to identify modifiable patient factors that were associated with increased LOS and facility discharge after TKA.

METHODS—Prospective data were reviewed from 716 consecutive, primary TKA procedures performed by 2 arthroplasty surgeons between 2006 and 2012 at a single institution. Preoperative body mass index (BMI), Veterans Rand-12 (VR-12) physical component score (PCS), and hemoglobin level were collected in addition to patient demographics and surgical details.

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!Dr. Tomek reports an educational consultancy for Smith and Nephew, which concluded during the revisions process.

Conflict of interest
There were no other reported conflicts.

Multivariate linear and logistic models were constructed to predict LOS and facility discharge, respectively.

RESULTS—After adjustment, higher BMI was associated with increased LOS in a dose-response effect: Compared to normal weight (BMI <25) overweight (25–29.9) was associated longer LOS by 0.32 days (P=0.038), class-I obesity (30–34.9) by 0.33 days (P=0.024), class-II obesity (35–39.9) by 0.67 days (P=0.012) and class-III obesity (>40) by 1.15 days (P<0.001). Class-III obesity also was associated with facility discharge (odds ratio=2.08, P=0.008). Poor PCS was associated with increasing LOS: compared to PCS≥50, PCS 20–29 was associated with a LOS increase of 0.40 days (P=0.014) and PCS<20 with a LOS increase of 0.64 days (P=0.031).

CONCLUSION—Patient BMI has a dose-response effect in increasing LOS. Poor PCS was associated with increased LOS in a similar dose-response manner. These associations for of BMI and PCS suggest that improvement preoperatively, by any amount, may potentially translate to decreased LOS and perhaps lower the cost associated with TKA.

Keywords

Total knee arthroplasty; physical function; body mass index; length of stay; facility discharge

INTRODUCTION

Osteoarthritis (OA) of the knee is a significant source of pain and disability, and total knee arthroplasty (TKA) is an effective treatment that relieves pain and restores function after non-operative modalities fail[1–3]. Changing population demographics and increasing obesity contribute to an increasing incidence of knee OA[4–6]. Lifetime risk of being diagnosed with severe knee OA is more than 13% in males and 18% in females and approximately half of these individuals will undergo a TKA[7]. Current projections estimate that 1,375,574 TKA procedures will be performed in 2020, up from the 719,000 procedures performed in 2009[8,9].

Although TKA is a cost-effective procedure, it is also costly[10–13]. With reimbursement lagging behind the rate of expense inflation[8,14], cost containment is a major issue[15]. Hospital length of stay (LOS)[16] and discharge to an inpatient facility[17] are among the most costly aspects of TKA, and they are potentially modifiable. Across various study types and locations, authors have identified increasing age[18–26], female sex[18,20,22,23,25], preoperative use of walking aids[20,21,24,26], high body mass index (BMI)[23,27], low preoperative physical function[20,21,26], and low preoperative hemoglobin (Hb)[21,22,26,28] as predictors of increasing LOS. In other investigations, increasing age[29–32], female sex[29–32], high BMI[27], presence of medical comorbidities[32], low preoperative health-related quality of life (HRQoL) survey score[17], and low preoperative physical function[30] were predictive of discharge to an inpatient facility. However, there is variation among the reported associations, especially in regards to BMI, and little published in respect to preoperative patient-reported physical function. We hypothesized that in a cohort of consecutive, unilateral, primary TKA patients high BMI and low preoperative patient-reported physical function would predict increased LOS and discharge to an inpatient facility. Furthermore, we hypothesized that additional patient characteristics, female sex, older age, and preoperative anemia, are also independently associated with prolonged LOS and institutional discharge.

PATIENTS AND METHODS

This study included a consecutive cohort of TKA patients between January 2006 and June 2012 at a single, tertiary, academic center by two fellowship-trained joint reconstruction orthopaedic surgeons. Institutional Review Board (IRB) approval was obtained prior to obtaining data. Using internal databases linked to the electronic medical record (EMR) systems, patients were selected by date and Current Procedural Terminology (CPT) code for primary TKA (27447). Patients undergoing bilateral procedures, simultaneous and staged within one year, were excluded. Concomitant arthroplasty or ligament repair on the ipsilateral extremity was the only other exclusion. No patients were admitted prior to the date of surgery. All patients obtained appropriate medical clearances prior to surgery.

We identified each patient's demographic information including age at surgery, sex, BMI, number of medical comorbidities, and smoking status (never smoked, currently smoking, former smoker). Modifiable variables, such as BMI and smoking status, were collected at the preoperative visit. BMI was grouped into categories based on the World Health Organization (WHO) classification: normal (< 25 kg/m^2), overweight (25–29. 9), class I obesity (30–34.9), class II obesity (35–39.9), and class III, morbid, obesity (> 40)[33,34]. In addition to inpatient perioperative details (dates of surgery, admission, and discharge to ascertain LOS, surgeon, and discharge disposition), we collected preoperative Hb values. Hb was considered low based on the WHO classification of anemia: < 12 g/dL for females and < 13 g/dL for males[35]. Discharge disposition was dichotomized into either home or inpatient facility. The specific discharge dispositions and their assigned category are shown in Table 1.

Prospectively collected, patient-reported outcome measures (PROM), including Veterans RAND 12 item health survey (VR-12) physical component score (PCS), were also recorded at each office visit, including the preoperative visit, as a standard of our institutional care pathway. VR-12 is a patient-administered questionnaire which quantifies a physical component score (PCS) based on patient responses using a non-proprietary scoring algorithm developed from Short Form 12/36 (SF-12/SF-36®)[36]. A lower PCS indicates poorer self-reported physical function. Comorbidities were identified based on the International Classification of Disease, Ninth Revision (ICD-9) algorithm developed by Deyo as a modification to the Charlson Comorbidity Index[37]. Those ICD-9 codes used are shown in Appendix 1.

Our initial EMR search discovered 1126 patients undergoing 1236 TKA. A total of 517 TKA were excluded as bilateral TKA as defined previously. Three procedures were excluded due to ipsilateral medial collateral ligament repair, ipsilateral total femur arthroplasty, and incorrect coding (total hip arthroplasty performed). A total of 716 (57.9%) consecutive, unilateral TKA in 679 (60.3%) patients were therefore included in the analysis. Of these 679 patients, 37 had a contralateral TKA more than one year apart and thus two separate TKA procedures were evaluated as unique procedures for the same patient. Manual chart review was performed for any missing variables in the initial database search.

Statistical analyses were performed using Stata 12MP (StataCorp. College Station, TX: StataCorp LP, 2012). Variable range definitions such as age, were grouped together using standard conventions as data variance allowed. We constructed multivariate models for predicting increasing LOS and discharge to inpatient facility using available variables based on our hypothesis. Linear regression and logistic regression techniques were used for LOS and discharge to inpatient facility, respectively. We used standard P-values of less than 0.05 to indicate statistical significance. We had sufficient sample size for these analyses. As an example, a power analysis indicated that we had 0.88 power to detect a difference of 0.2 days for LOS. We used robust standard errors and clustered on each patient to account for observational data that included 37 patients that were in the data twice for unilateral TKA at different times within our selected period.

RESULTS

The patient cohort consisted of 59% female and 41% male patients with a mean age (SD) of 63.4 years (11.3). The mean preoperative BMI and VR-12 PCS were 31.7 (16.63–66.0) and 32.3 (8.7–71.8), respectively.

LOS model variables are shown in Table 2. With a reference age of less than 55 years, age greater than 55 had a significant increase in LOS. Age of 55–64 years had an increased adjusted stay of 0.35 days (P=0.049), age of 65–74 years had an increased adjusted stay of 0.62 days (P<0.001), and age of 75–90 years had an increased adjusted stay of 0.78 days (P<0.001). Female sex also predicted a significant adjusted stay of 0.47 days (P<0.001). Increasing BMI predicted a prolonged LOS with evidence of a significant dose-response relationship: overweight added 0.32 days (P=0.038), class I obesity added 0.33 days (P=0.024), class II obesity added 0.67 days (P=0.012), and class III obesity added 1.15 days (P<0.001). Low preoperative hemoglobin levels had an adjusted increase in LOS of 0.87 days (P=0.002).

Lower preoperative VR-12 Physical Component Scores (PCS) were associated with increasing LOS: VR-12 PCS of 20–29 had an increased LOS of 0.40 days (P=0.014) and VR-12 PCS less than 20 had an increased LOS of 0.64 days (P=0.031). Neither smoking, presence of comorbidities, nor operating surgeon had statistically significant association with LOS.

Discharge to an inpatient facility compared to home followed a similar pattern as LOS, as shown in Table 3. Age of 55–64 years had an adjusted odds ratio (OR) of 2.03 (P=0.043), age of 65–74 years had an adjusted (OR) of 2.89 (P=0.004) and age greater than 75 years had an adjusted OR of 11.95 (P<0.001) of discharge to an inpatient facility rather than home. Female sex had an adjusted OR of 1.85 (P=0.010) of discharge to an inpatient facility. BMI over 40 kg/m^2, class III (morbid) obesity, was the only obesity category which predicted inpatient discharge disposition with an adjusted OR of 2.38 (P=0.021).

Smoking and operating surgeon had no significant association with discharge to an inpatient facility. However, unlike LOS, having one or more medical comorbidities was associated with discharge to an inpatient facility, adjusted OR of 2.08 (P=0.008). Low preoperative Hb level carried an adjusted OR of 2.68 (P≤0.001) for discharge to an inpatient facility. Only the lowest self-reported VR-12 PCS (<20) had a significant adjusted OR of 5.30 (P=0.013) for discharge to an inpatient facility.

DISCUSSION

With projections of increasing rates of TKA in the United States[4,8], there is a continued and energized movement to minimize the utilization of resources to decrease cost[38]. LOS and discharge destination are two large components of the full cost of TKA that are also essential to patient satisfaction and postoperative recovery. In this study, we identified preoperative patient characteristics that predict length of stay and discharge disposition including a dose-response effect with BMI and patient-reported physical function (VR-12 PCS).

While other studies have inconsistently demonstrated an effect of BMI on LOS[20,21,23,26,27], we demonstrate a clear, meaningful, dose-response predictive effect between increasing preoperative BMI and LOS. There exists a statistically significant association with LOS for all BMI categories above normal (≥25 kg/m^2). Starting with the overweight category, adjusted LOS increases with increasing significance for each category of increasing BMI. Morbid obesity, the class III obesity, is associated with an increased LOS of 1.15 adjusted days and more than doubles the odds of being discharged to an inpatient facility. Recently, D'Apuzzo et al. identified morbidly obese (BMI > 40) patients undergoing TKA from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (HCUP NIS) database, matched this patient group to a non-obese comparison group, and concluded that morbid obesity was associated with increase resource utilization after TKA[27]. However, they only looked at class III obesity (morbidly obese) as defined by ICD-9 code and not BMI value, and this demonstrated a minimally different LOS (3.6 days versus 3.5 days, P<0.001) and a slightly higher rate of discharge to an inpatient facility (40% versus 30%). Our findings suggest a much greater association of increasing BMI to LOS. Not only is morbid obesity highly associated with LOS, the overweight BMI category increases LOS by a statistically significant, adjusted 0.32 days. This increasing association effect with increasing BMI suggests a true dose-response relationship BMI and LOS, suggesting that any improvement in weight loss, and thus BMI, may have a decreasing effect on LOS. We are unaware of any other report predicting a dose-response association between LOS and BMI following primary TKA.

In this study we also demonstrate that poor preoperative self-reported physical function (VR-12 PCS) was predictive of both increased LOS and discharge to an inpatient facility. To our knowledge there has previously been little evidence that preoperative PROM are predictive of length of stay, discharge disposition, or other markers of resource utilization[17,20,39]. Dall et al. reported a correlation between high preoperative SF-36 health perception score and shorter length of stay, but other SF-36 scores were not significant in the multivariable regression[39]. Sharereh et al. found a significant relationship between low preoperative EuroQol 5D (EQ-5D) and institutional discharge, but no correlation between preoperative SF-12 PCS[17]. PROMs have been widely adopted as a method to look at changes in physical and mental function over time through regular data collection from a more genuine perspective, the patient's. However, our findings suggest that preoperative

PROMs may be predictive of increased LOS and discharge to an inpatient facility. Moreover, the effect has a dose-response association for LOS. When compared to the reference group of VR-12 PCS greater than 50, LOS increased by an additional 0.40 adjusted days for VR-12 scores 20–29, and scores less than 20 increased by an additional 0.64 days. While preoperative physical function, as assessed by stair climbing and use of mobility aids, has been previously reported to predict LOS and discharge to an inpatient facility[17,19–21,30,32,40], there is no reported association between preoperative patient-reported overall physical function, measured here by VR-12 PCS, and LOS and discharge to an inpatient facility.

Advancing age has been demonstrated to be a predictor of increased resource utilization in TKA, both for length of stay and discharge to an inpatient facility[18,20,22,24,25,29,31,41]. Our findings would suggest that increasing age has an increasing association with both LOS and discharge to an inpatient facility. Adjusted OR for discharge to an inpatient facility and adjusted days for LOS increase with each age category. Smith et al. documented a similar dose-response effect with an increase in LOS by 10–13% for each decade of age[26]. Bozic, et al. analyzed 3333 consecutive TKA from a mixed cohort and demonstrated that age greater than 65 years and female sex were predictive of discharge to an extended care facility (ECF)[31]. For those undergoing TKA, patients over 80 years of age were 5.4 times more likely to be discharged to an ECF. These numbers share a similar trend with our findings, yet our outcomes suggest that those aged 75–90 years have an even greater adjusted OR (11.95, $P<0.001$) for discharge to an inpatient facility. We also found female sex predictive of both LOS and discharge to an inpatient facility, as reported previously[22,25,29,31].

Our analysis demonstrates that low preoperative Hb levels predict increased length of stay. There have been few investigations which show preoperative Hb levels, not transfusion, to be predictive of LOS for a TKA cohort[21,22]. Monsef et al. recently examined a cohort of TKA patients and identified preoperative hemoglobin as negatively correlated with length of stay but transfusion was the stronger predictor of increased LOS[28]. Additionally, preoperative anemia predicts discharge to an inpatient institutional rehab (adjusted OR = 2.68); this is a finding not currently documented in the reviewed literature.

A potential limitation of the study is that it was performed at a single institution with two surgeons. At the same time, this does minimize disparity among other hospital- and surgeon-level variables since they shared facilities, staff, postoperative protocols, and discharge criteria. Although we did not focus on postoperative factors, LOS and discharge disposition may influence each other. For example, logistical delays for facility discharges, such as waiting for a rehabilitation bed to become available, may lengthen the LOS itself. Additional limitations include limited perioperative details (such as not having anesthesia and implant information) and the dichotomization of discharge disposition. While dichotomizing discharge disposition increases the power to detect a difference, it also decreases the specificity.

Inherent factors such as age and sex cannot be modified to decrease LOS or discharge to an inpatient facility. However, it is unclear to what end modifying other preoperative factors should be pursued. Kotzé describes significant decrease in LOS following the implementation of a blood management program at a single hospital in the United

Kingdom[42]. Other patient factors, such as BMI and VR-12 PCS, may be less easily modifiable. It is unclear how feasible addressing weight loss and physical function would be in making a significant change in BMI and VR-12 PCS, respectively. However, both of these variables have a clear dose-response effect. This suggests that improvement in these variables would predict less resource utilization, thus attaining a specific "cut-off" may be less important. Beaupre demonstrated a trend toward decreasing LOS with preoperative physical rehabilitation, although it had no effect on the preoperative nor the postoperative PROM (SF-36)[43]. However, based on the findings of our study, an improvement in either of those two patient characteristics, BMI and VR-12 PCS, may predict a decreased LOS and a lower rate of discharge to an inpatient facility, thus reducing patient burden and resource utilization. Lastly, as in most clinical studies, there are numerous possibilities for statistical approach, variable definitions, and general model fit. In our work, for example, one could argue for using a Poisson regression model for LOS and using continuous age instead of age groups. However, using those strategies, there were no differences in our general results or overall conclusions (data not shown).

CONCLUSION

In this prospective, consecutive cohort of unilateral TKA, we identify certain patient factors that are predictive of increasing LOS and institutional discharge: increasing age, female sex, increasing obesity, preoperative anemia, and low preoperative VR-12 PCS. This current study reconfirms the findings of previous studies and identifies new details regarding preoperative patient factors and their association with increased LOS and discharge to an inpatient facility. Furthermore, we present a dose-response effect of BMI and VR-12 PCS on LOS which has not yet been described.

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Dr. Keeney reports paid consulting work by Berkley Medical Management Solutions (Kansas City, MO, USA) on matters related to worker's compensation insurance data with no particular focus on orthopaedics.

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Table 1

Discharge disposition and categorization.

Discharge Disposition	Home	Inpatient Facility	% of Total
Custodial Care	1		0.14
Home	48		6.70
Home with Visiting Nurse	509		71.09
Acute Rehabilitation		24	3.35
Skilled Nursing Facility (SNF)		76	10.61
Stand-Alone Rehabilitation Facility		9	1.26
Swing Bed		41	5.73
General Rehabilitation		6	0.84
Rehabilitation Center		2	0.28
	558 (77.93)	158 (22.07)	716 (100.00)

Table 2

Preoperative predictors of LOS among patients undergoing primary TKA, N = 716*

Variables	Counts§ % (n)	Adjusted Days¥	Adjusted 95% CI	Adjusted P
Age at Surgery (ref ≤ 55 years)	24 (171)			
55 – 64	31 (225)	0.35	0.001 – 0.71	**0.049**
65 – 74	26 (186)	0.62	0.28 – 0.96	**<0.001**
75 – 90	19 (134)	0.78	0.40 – 1.17	**<0.001**
Sex (ref = Male)	41 (291)			
Female	59 (425)	0.40	0.17 – 0.63	**<0.001**
BMI (ref = Normal, < 25 kg/m^2)	16 (116)			
Overweight (25–29.9 kg/m^2)	32 (225)	0.32	0.02 – 0.62	**0.038**
Class I Obesity (30–34.9 kg/m^2)	25 (179)	0.33	0.04 – 0.61	**0.024**
Class II Obesity (35–39.9 kg/m^2)	14 (99)	0.67	0.15 – 1.20	**0.012**
Class III Obesity (>40 kg/m^2)	13 (95)	1.15	0.64 – 1.66	**<0.001**
Smoking (ref = Never smoked)	42 (298)			
Used to smoke	45 (320)	0.15	−0.08 – 0.37	0.203
Currently smoking	13 (95)	0.30	−0.13 – 0.73	0.170
Comorbidities (ref = 0)	87 (625)			
≥ 1 co-morbidity	13 (91)	0.34	−0.08 – 0.76	0.116
Operating Surgeon (ref = Surgeon 1)				
Surgeon 2	46 (329)	−0.17	−0.37– 0.03	0.104
*Hemoglobin*ϒ (ref = Normal)	87 (623)			
Low	13 (93)	0.87	0.32 – 1.49	**0.002**
VR-12 Physical Pre-Op Score# (ref ≥ 50)	5 (36)			
40–49	17 (115)	0.04	−0.24 – 0.32	0.765
30–39	35 (231)	0.20	−0.09 – 0.49	0.178
20–29	32 (214)	0.40	0.08 – 0.72	**0.014**
<20	11 (73)	0.64	0.05 – 1.22	**0.031**

*We used robust standard errors due to observational data and clustered upon patient ID to account for 37 patients (5.2%) who underwent separate unilateral primary TKA at different time periods. All variables are adjusted for the other variables in the model. Missing values are included as their own category, but are not displayed.

§Counts and percentages may not add up to 716 and 100 due to missingness and rounding, respectively.

¥Coefficient value represents days.

[r]WHO recommendations define normal levels as ≥ 13 g/dL for men and ≥ 12 g/dL for women. Our patients in the "Normal" categories have ranges of 13.0 – 18.3 g/dL and 12.0 – 16.7 g/dL, respectively. In the "Low" category, the ranges are 7.4 – 12.9 g/dL for men and 7.1 – 11.9 gm/dL for women.

[#]A lower VR-12 score is an indicator of worse self-reported physical health.

Table 3

Preoperative predictors of discharge to an inpatient facility, compared to home, among patients undergoing primary TKA, N = 716*

Variables	Home % § (n) (N = 558, 78%)	Rehab % § (n) (N = 158, 22%)	Adjusted Odds Ratio	Adjusted 95% CI	Adjusted P
Age at Surgery (ref ≤ 55 y)	88 (151)	12 (20)			
55 – 64	84 (190)	16 (35)	2.03	1.02 – 4.04	**0.043**
65 – 74	79 (147)	21 (39)	2.89	1.39 – 6.01	**0.004**
75 – 90	52 (70)	48 (64)	11.95	5.37 – 26.61	**<0.001**
Sex (ref = Male)	83 (241)	17 (50)			
Female	75 (317)	25 (108)	1.85	1.16 – 2.94	**0.010**
BMI (ref = Normal, < 25 kg/m^2)	76 (88)	24 (28)			
Overweight (25–29.9 kg/m^2)	80 (180)	20 (45)	1.12	0.60 – 2.14	0.724
Class I Obesity (30–34.9 kg/m^2)	83 (149)	17 (30)	0.90	0.44 – 1.72	0.755
Class II Obesity (35–39.9 kg/m^2)	77 (76)	23 (23)	1.20	0.56 – 2.47	0.626
Class III Obesity (> 40 kg/m^2)	67 (64)	33 (31)	2.38	1.14 – 4.97	**0.021**
Smoking (ref = Never smoked)	76 (227)	24 (71)			
Used to smoke	79 (252)	21 (68)	0.83	0.52 – 1.31	0.422
Currently smoking	82 (78)	18 (17)	1.07	0.53 – 2.14	0.857
Comorbidities (ref = 0)	81 (507)	19 (118)			
≥ 1 co-morbidity	56 (51)	44 (40)	2.08	1.21 – 3.57	**0.008**
Operating Surgeon (ref = Surgeon 1)	76 (293)	24 (94)			
Surgeon 2	81 (265)	19 (64)	0.88	0.59 – 1.32	0.539
Hemoglobin ϒ (ref = Normal)	81 (507)	19 (116)			
Low	55 (51)	45 (42)	2.68	1.55 – 4.63	**≤0.001**
VR-12 Physical Pre-Op Score # (ref ≥ 50)	86 (31)	14 (5)			

Variables	Home % § (n) (N = 558, 78%)	Rehab % § (n) (N = 158, 22%)	Adjusted Odds Ratio	Adjusted 95% CI	Adjusted P
40–49	86 (99)	14 (16)	1.11	0.31 – 3.96	0.875
30–39	84 (194)	16 (37)	1.33	0.38 – 4.34	0.645
20–29	73 (156)	27 (58)	2.84	0.83 – 9.72	0.096
<20	63 (46)	37 (27)	5.25	39 – 19.90	**0.015**

*We used robust standard errors due to observational data and clustered upon patient ID to account for 37 patients (5.2%) who underwent separate primary TKA at different intervals. Missing values are included as their own category, but are not displayed.

§Counts and percentages may not add up due to missingness and rounding, respectively. Percentages per column equal 100% in each row for home and inpatient discharge disposition.

ϒWHO recommendations define normal scores as ≥ 13 g/dL for men and ≥ 12 gm/dL for women. Our patients in the “Normal” categories have ranges of 13.0 – 18.3 g/dL and 12.0 – 16.7 g/dL, respectively. In the “Low” category, the ranges are 7.4 – 12.9 g/dL for men and 7.1 – 11.9 g/dL for women.

#A lower VR-12 score is an indicator of worse self-reported physical health.