INTRODUCTION

Total knee arthroplasty (TKA) is the most common arthroplasty in the United States. The elderly, obese, and those with multiple comorbidities are at increased risk of developing complications, leading to high readmission rates. With increases in these patient factors, complications and readmission rates may continue to rise in patients undergoing TKA. Preoperative comorbidities, like cardiac disease, chronic obstructive pulmonary disease (COPD), diabetes mellitus, and obesity, increase the likelihood of postoperative complications. Demographic factors, such as age, sex, and race, also contribute to increased risk. Readmission rates after TKA are under scrutiny in the United States since the implementation of Medicare Hospital Readmission Avoidance Program in 2012.

ABSTRACT

Objective: To identify independent risk factors, complications, and early hospital readmission following total knee arthroplasty. Methods: Using the ACS-NSQIP database, we identified patients who underwent primary TKA from 2012-2015. The primary outcome was early hospital readmission. Patient demographics, preoperative comorbidities, laboratory data, operative characteristics, and postoperative complications were compared between readmitted and non-readmitted patients. Logistic regression identified independent risk factors for 30-day readmission. Results: 137,209 patients underwent TKA; 3.4% were readmitted within 30 days. Advanced age, male sex, black ethnicity, morbid obesity, presence of preoperative comorbidities, high ASA classification, and increased operative time were independently related risk factors. Asian and no reported race were negative risk factors. Postoperative complications: acute myocardial infarction, acute renal failure, stroke, pneumonia, pulmonary embolism, and deep vein thrombosis show positive associations. Conclusions: Advanced age, male sex, black ethnicity, morbid obesity, presence of comorbidities, high ASA classification and long operative time are independent risk factors for postoperative complications and early hospital readmission following total knee arthroplasty. Level of Evidence III, Case control study.

Keywords: Arthroplasty. Knee. Patient readmission. Risk factors.

RISK FACTORS FOR EARLY HOSPITAL READMISSION FOLLOWING TOTAL KNEE ARTHROPLASTY

FATORES DE RISCO DE REINTERNAÇÃO HOSPITALAR PRECOCÊ APÓS ARTROPLASTIA TOTAL DO JOELHO

EVA J. LEHTONEN,1 MATTHEW C. HESS,1 GERALD McGWIN JR.,2 ASHISH SHAH,1 ALEXANDRE LEME GODOY-SANTOS,3 SAMEER NARANE1

1. University of Alabama at Birmingham, Department of Orthopedic Surgery, Birmingham, AL, United States.
2. University of Alabama at Birmingham, Department of Public Health, Birmingham, AL, United States.
3. Hospital da Clinicas HCFMUSP, Faculdade de Medicina, Universidade de Sao Paulo, Sao Paulo, SP, Brasil.

RESUMO

Objetivo: Identificar fatores de risco independentes, complicações e reinternação precoce após artroplastia total do joelho. Métodos: A partir de banco de dados ACS-NSQIP, identificamos pacientes submetidos à ATJ primária de 2012 a 2015. O desfecho primário foi a reinternação hospitalar precoce. Dados demográficos, comorbidades pré-operatórias, dados laboratoriais, características cirúrgicas e complicações pós-operatórias foram comparadas entre os pacientes reinternados e não reinternados. A regressão logística identificou fatores de risco independentes para a reinternação em 30 dias. Resultados: Foram identificados 137.209 pacientes submetidos à ATJ, sendo que 3,4% foram reinternados no período de 30 dias. A idade avançada, o sexo masculino, a raça negra, a obesidade mórbida, a presença de comorbidades pré-operatórias, a alta classificação ASA e o aumento do tempo cirúrgico foram fatores de risco relacionados independentemente. A raça asiática e as não relatadas foram fatores de risco negativos. As complicações pós-operatórias infarto agudo do miocárdio, insuficiência renal aguda, acidente vascular cerebral, pneumonia, embolia pulmonar e trombose venosa profunda apresentaram associações positivas. Conclusões: Idade avançada, sexo masculino, raça negra, obesidade mórbida, presença de comorbidades, classificação ASA elevada e tempo cirúrgico prolongado são fatores de risco independentes de complicações pós-operatórias e reinternação precoce após artroplastia total do joelho. Nível de evidência III, Estudo de caso de controle.

Descritores: Artroplastia. Joelho. Readmissão do paciente. Fatores de risco.
RESULTS

A total of 137,209 patients were included in the study. The overall 30-day readmission rate for patients after primary TKA was 3.4% (4,668 of 137,209 patients).

The average age for patients in this study was 66.6 years. Older age, male sex, black race, and higher BMI category were significant (p<0.0001) demographic factors positively associated with readmission (Table 1 and Table 2). Asian and unreported race were significant (p<0.0001) demographic factors negatively associated with readmission (Table 1 and Table 2). For the medical comorbidities, smoking, insulin-dependent vs non-insulin-dependent diabetes, dialysis use, hypertension, congestive heart failure, dyspnea, COPD, bleeding disorder, preoperative open wound and wound infection, as well as corticosteroid use were significantly (p<0.0001) positively associated with readmission. Laboratory values such as elevated WBC count, low hematocrit, low platelets, elevated creatinine, low serum albumin, and elevated INR were also significantly (p<0.0001) positively associated with readmission. Other operative variables, such as increased operation time, use of general anesthesia vs other techniques, and increased time from operation to discharge also demonstrated significant (p<0.0001) positive associations with readmission.

All variables shown in Table 3 demonstrated statistically significant (p<0.0001) positive associations with readmission. The overall complication rate among readmitted patients was 58.0% (6,143 of 13,720 patients) compared to 10.4% among non-readmitted patients. Among readmitted patients, 32.4% developed medical complications and 25.6% developed surgical complications.

Each year of increasing age (OR, per year: 1.02; 95% CI, 1.02 to 1.03) and black vs white race (OR, black vs white race: 1.24; 95% CI, 1.11 to 1.37) were significant independent positive risk factors for 30-day readmission. Female vs male sex (OR, female vs male: 0.78; 95% CI, 0.73 to 0.83), Asian vs white race (OR, Asian vs white race: 0.62; 95% CI, 0.48 to 0.80), and unknown or unreported vs white race (OR, unknown vs white race: 0.87; 95% CI, 0.78 to 0.96) demonstrated significant protective effects. Morbidly obese patients had significantly higher odds of readmission than overweight patients (OR: 1.20; 95% CI, 1.08 to 1.32). Patients with ASA class 4 had more than twice the odds of being readmitted compared to those with ASA class 2 (OR: 2.06; 95% CI, 1.73 to 2.44). Patients with ASA class 3 also had significantly higher odds of readmission compared to those with ASA class 2 (OR: 1.43; 95% CI, 1.34 to 1.53). Each additional minute of operative time was found to be an independent positive risk factor for readmission (OR per minute: 1.002; 95% CI, 1.002 to 1.003). The presence of one or more preoperative comorbidity was positively associated with readmission compared to patients with no comorbidities (OR: 1.29; 95% CI, 1.25 to 1.34, p<0.0001). (Table 2)

All postoperative complications included in the multivariate analysis demonstrated significant independent associations with readmission (Table 3). Patients who were readmitted had over ten-times the odds of postoperative superficial surgical site infection, pulmonary embolism, or deep vein thrombosis.
The number of TKA being performed across the U.S is increasing, presenting a challenge in a rapidly changing healthcare landscape. Changing patient demographics and regulations creating financial penalties for adverse patient outcomes has created an incentive for scrutiny in this area. A previous study of the ACS-NSQIP database from 2011 found that older age, male gender, positive cancer history, elevated BUN, presence of a bleeding disorder, and high ASA score were shown to be positive predictors of readmission, though, this focused on all joint arthroplasties. However, with TKA being the most common performed arthroplasty along with the availability of multiple years of additional data, it is necessary to update and refine our understanding of factors influencing readmission following TKA.

Our analysis of the data from a cohort of 137,209 patients from 2012-2015 found that the 30-day readmission rate following TKA was 3.4%. Many demographic characteristics, preoperative comorbidities, laboratory abnormalities and postoperative complications were associated with higher rates of readmission following TKA. Increasing age, male sex, black race, morbid obesity, presence of one or more comorbidities, postoperative complications, ASA class 3 or 4, and longer operation time demonstrated significant, independent positive associations with 30-day readmission following TKA. Our study’s 30-day readmission rate (3.4%) is consistent with existing literature; 30-day readmission rates following TKA have been reported between 2.4% - 5.8%. Our study reports a lower rate than the ACS-NSQIP database (3.4% vs 4.6%), which may suggest that regulatory efforts and risk reduction initiatives in recent years have had a positive effect. This is consistent with an institutional cohort by Keeney et al which showed that introduction of risk reducing initiatives significantly reduced readmission rates following TKA.

### Table 1. Preoperative and Operative Characteristics.

| Variable                  | Not Readmitted* (N=132,541) | Readmitted* (N=4,668) | P Value | Variable                  | Not Readmitted* (N=132,541) | Readmitted* (N=4,668) | P Value |
|---------------------------|-------------------------------|------------------------|---------|---------------------------|-------------------------------|------------------------|---------|
| Age                       | 66.53 (48.9)                 | <0.0001                |         | Pre-op blood transfusion  | 67 (6.1%)                  | 7 (0.2%)               | 0.004  |
| Sex                       |                               | <0.0001                |         | Systemic Sepsis           | 241 (0.2%)                  | 15 (0.3%)              | 0.16    |
| Male                      | 49.856 (37.6%)               | 2.039 (43.7%)          |         | SIRS                      | 5 (0.0%)                   | 0 (0.0%)               | <0.0001 |
| Female                    | 82.685 (62.4%)               | 2.629 (56.3%)          |         | Septic Shock              | 5 (0.0%)                   | 0 (0.0%)               | <0.0001 |
| Race                      |                               | <0.0001                |         | Corticosteroid use        | 4.675 (3.5%)               | 260 (5.6%)             | <0.0001 |
| White                     | 103.659 (78.2%)              | 3.691 (79.1%)          |         | ASA class                 | 80.225                      | 4 (0.0%)               | <0.0001 |
| Asian                     | 9.567 (7.2%)                 | 440 (9.4%)             |         | Operative time# (min)     | 93.59 (55.24 - 131.94)     | 97.78 (53.78 - 141.78) | <0.0001 |
| American Indian           | 2.845 (2.2%)                 | 63 (1.4%)              |         | Operation time# (per min) | 1.002 (1.002 to 1.003)     | 1.002 (1.002 to 1.003) | <0.0001 |
| Native Hawaiian           | 418 (0.3%)                   | 9 (0.2%)               |         | Operation time# (per min) | 1.002 (1.002 to 1.003)     | 1.002 (1.002 to 1.003) | <0.0001 |
| Unreported                | 15.341 (11.6%)               | 450 (9.6%)             |         | Operation time# (per min) | 1.002 (1.002 to 1.003)     | 1.002 (1.002 to 1.003) | <0.0001 |
| BMI Category              |                               | <0.0001                |         | Operation time# (per min) | 1.002 (1.002 to 1.003)     | 1.002 (1.002 to 1.003) | <0.0001 |
| Preoperative Labs         |                               | <0.0001                |         | Operation time# (per min) | 1.002 (1.002 to 1.003)     | 1.002 (1.002 to 1.003) | <0.0001 |
| Operative Variables       |                               | <0.0001                |         | Operation time# (per min) | 1.002 (1.002 to 1.003)     | 1.002 (1.002 to 1.003) | <0.0001 |

* Some data points were unrecorded and were therefore unavailable for inclusion in the evaluation. ¥ The values given represent the average age of patients, in years. The values are given as a number of patients, with the percentage in parentheses. The values given represent an average, with 1 standard deviation in parentheses.

### Table 2. Preoperative and Operative Characteristics as Risk Factors for Readmission After Total Knee Arthroplasty.

| Variable                  | Odds Ratio (95% CI) | P Value |
|---------------------------|--------------------|---------|
| Preoperative Characteristics|                    |         |
| Age (per year)            | 1.021 (1.018 to 1.025) | <0.0001 |
| Sex female vs male        | 0.78 (0.73 to 0.83) | <0.0001 |
| Race                      |                    | <0.0001 |
| Black vs White            | 1.24 (1.11 to 1.37) | <0.0001 |
| Asian vs White            | 0.62 (0.48 to 0.80) | 0.0002  |
| Native Hawaiian vs White  | 0.58 (0.30 to 1.13) | 0.1118  |
| American Indian vs White  | 0.60 (0.36 to 1.00) | 0.0514  |
| Non reported vs White     | 0.87 (0.78 to 0.96) | 0.0048  |
| BMI Category              |                    |         |
| Underweight vs Overweight | 1.06 (0.56 to 1.99) | 0.8670  |
| Normal vs Overweight      | 1.11 (0.99 to 1.23) | 0.0750  |
| Obese vs Overweight       | 0.96 (0.88 to 1.04) | 0.2742  |
| Very obese vs Overweight  | 0.92 (0.84 to 1.04) | 0.0715  |
| Morbidly Obese vs Overweight | 1.20 (1.08 to 1.32) | 0.0033  |
| Comorbidities             | 1.29 (1.25 to 1.34) | <0.0001 |
| Operative variables       |                    |         |
| ASA class                 |                    |         |

DISCUSSION

The number of TKA being performed across the U.S is increasing, presenting a challenge in a rapidly changing healthcare landscape. Changing patient demographics and regulations creating financial penalties for adverse patient outcomes has created an incentive for scrutiny in this area. A previous study of the ACS-NSQIP database from 2011 found that older age, male gender, positive cancer history, elevated BUN, presence of a bleeding disorder, and high ASA score were shown to be positive predictors of readmission, though, this focused on all joint arthroplasties. However, with TKA being the most common performed arthroplasty along with the availability of multiple years of additional data, it is necessary to update and refine our understanding of factors influencing readmission following TKA.

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Readmitted patients had more than 18 times higher odds of experiencing MI prior to surgery may help decrease readmission. Acute renal failure (Odds Ratio 15.26) and other pulmonary complications (ventilator use, pneumonia, and unplanned intubation) were close behind MI as high magnitude positive risk factors of readmission. While a cardiopulmonary exam and basic renal function panel are staples of the preoperative assessment, our results emphasize the importance of thorough preoperative workup when attempting to reduce hospital readmissions. Many surgeons require a note from the primary care provider before a total knee replacement or that patients demonstrate a certain level of cardiopulmonary fitness prior to surgery. Standardized preoperative assessments and further identification of patients at risk of developing these complications may help reduce readmission after TKA. Postoperative deep venous thrombosis and pulmonary embolism were also high magnitude independent risk factors for readmission (Odds Ratio 16.45 and 10.32, respectively). While the majority of institutions and physicians implement prophylactic pharmacologic anticoagulation in the postoperative period, our findings emphasize the importance of patient education and preventive care to decrease hospital readmissions within 30 days of surgery.

Aside from medical and surgical complications, very high ASA class was associated with the highest odds of readmission. Patients with ASA class 4 had more than twice the odds of readmission compared to ASA class 2. Similarly, patients with ASA class 3 had 1.43 times the odds of readmission than ASA class 2 patients. Multiple retrospective studies of individual institutions report similar findings. The ASA classification system is widely utilized and available as a reliable predictor of readmission risk after TKA. Better understanding of risk factors allows the development and implementation of evidence-based interventions aimed at mitigating risks and reducing 30-day readmission rates following TKA. These risk factors for readmission are already being utilized to reduce hospital costs; young patients with low ASA scores and few medical comorbidities are often discharged early (0-2 days) and these early discharges are not associated with increased complications or readmissions.

Information from this study can be used to identify and counsel high-risk patients prior to surgery. Continued research and understanding in this area will allow more informed discussion of each patient’s individual risks and benefits for undergoing TKA. We hope this information will be used by healthcare providers to improve the outcomes for patients undergoing TKA.

Table 3. Postoperative complications as risk factors for readmission after total knee arthroplasty.

| Overall complications | Not Readmitted \(^{a} \) (N=132,541) | Readmitted \(^{b} \) (N=4,658) | P Value \(^{f} \) | Odds Ratio (95% CI) \(^{g} \) | P Value \(^{h} \) |
|-----------------------|------------------------------------|-----------------------------|-----------|---------------------------|-----------|
| Medical complications |                                    |                             |           |                          |           |
| Pneumonia             | 327 (0.3%)                         | 176 (3.8%)                  | <0.0001   | 12.15 (10.04 to 14.71)   | <0.0001   |
| Unplanned intubation  | 138 (0.1%)                         | 66 (1.4%)                   | <0.0001   | 9.94 (7.35 to 13.46)     | <0.0001   |
| Urinary tract infection| 975 (0.7%)                         | 225 (4.8%)                  | <0.0001   | 6.22 (5.34 to 7.23)      | <0.0001   |
| Ventilator for more than 48 hours | 62 (0.1%) | 35 (0.8%) | <0.0001 | 11.16 (7.28 to 17.09) | <0.0001 |
| Stroke or cerebrovascular accident | 72 (0.1%) | 37 (0.8%) | <0.0001 | 12.18 (8.11 to 18.28) | <0.0001 |
| Acute renal failure   | 41 (0.0%)                          | 33 (0.7%)                   | <0.0001   | 15.26 (9.50 to 24.52)    | <0.0001   |
| Cardiac arrest        | 61 (0.1%)                          | 30 (0.6%)                   | <0.0001   | 7.18 (5.00 to 11.81)     | <0.0001   |
| Sepsis                | 32 (0.0%)                          | 57 (1.2%)                   | <0.0001   | 9.09 (6.38 to 12.77)     | <0.0001   |
| Myocardial infarction (MI) | 152 (0.1%) | 125 (2.7%) | <0.0001 | 18.48 (14.47 to 23.58) | <0.0001 |
| Blood transfusion     | 9,806 (7.4%)                       | 538 (11.5%)                 | <0.0001   | 1.41 (1.28 to 1.55)      | <0.0001   |
| Surgical complications|                                    |                             |           |                          |           |
| Superficial surgical site infection | 481 (0.4%) | 224 (4.8%) | <0.0001 | 13.53 (11.46 to 15.98) | <0.0001 |
| Deep or incisional surgical site infection | 49 (0.0%) | 164 (3.5%) | <0.0001 | 0.87 (0.56 to 1.36) | <0.0001 |
| Organ or space surgical site infections | 26 (0.0%) | 179 (3.8%) | <0.0001 | 1.18 (0.88 to 1.59) | <0.0001 |
| Pulmonary embolism    | 613 (0.5%)                         | 319 (6.8%)                  | <0.0001   | 16.45 (14.27 to 18.96)   | <0.0001   |
| Deep venous thrombosis| 913 (0.7%)                         | 309 (6.6%)                  | <0.0001   | 10.32 (9.02 to 11.82)    | <0.0001   |

* Some data points were unrecorded and were therefore unavailable for inclusion in the evaluation. The value are given as a number of patients, with the percentage in parentheses. ¶ P value from univariate modeling. ¥ The values are given as the odds ratio, with the 95% CI in parentheses. ‡ Logistic regression modeling adjusted for age, sex, race, and presence of one or more preoperative comorbidities, ASA class, and operative time. Not adjusted for concurrent medical or surgical complications.
the anticipation, prevention, and early detection of poor outcomes, leading to reduced cost and improved patient care. The results of this study should be interpreted in light of certain limitations. Demographically our patient sample was majority female (62.2%) and racially non-diverse. The overwhelming majority of patients were white (78.2%) or unreported (11.5%). Although we used a widely studied, validated database, errors in data entry or misclassifications may have occurred. This may be particularly important in calculated variables, such as BMI, which relies on the accuracy of both height and weight. This study was also limited by significant amounts of missing data in certain variables of interest.

CONCLUSION
This study was successful in identifying new variables associated with early readmission in patients undergoing TKA. Increasing age, male sex, black race, morbid obesity, the presence of preoperative comorbidities, high ASA class and increased operative time were significant positively associated independent risk factors rates following TKA.

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