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Predictors for Delayed Discharge after Total Joint Arthroplasty of the Hip and Knee

By

Ajay Premkumar

Degree to be awarded: MPH

Global Health

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Abstract Cover Page

Predictors for Delayed Discharge after Total Joint Arthroplasty of the Hip and Knee

By

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B.S.
Emory University, College of Arts and Sciences
2010

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Health
2016

ABSTRACT

Predictors for Delayed Discharge after Total Joint Arthroplasty of the Hip and Knee
by Ajay Premkumar

Background:
Total joint arthroplasty (TJA) is a common orthopaedic procedure that comprises a significant portion of US healthcare expenditures, particularly in the elderly. With the recent push towards value-based health care, predicting delays in discharge is crucial. Postoperative hypotension, a common side effect of major surgery, is a risk factor for prolonged recovery delayed discharge. While other risk factors for prolonged hospital stay have been identified in TJA patients, postoperative hypotension has been understudied in the orthopaedic literature. This study examines postoperative hypotension along with other potentially modifiable risk factors such as opioid use and laboratory anomalies and their relation to prolonged hospitalization after TJA. We hypothesize that the number of acute postoperative hypotensive events after TJA is associated with increased hospital length of stay.

Methods:
This retrospective cohort study identified 2561 primary total hip and total knee arthroplasty cases performed at a single institution between June 2012 and August 2014. We compared characteristics of cases with a hospital length of stay of less than two days to those with a hospital length of stay two days or longer. Our institution uses an accelerated physical therapy program, which may be interrupted by patient hypotension. As such, postoperative hypotension, pre and post-operative labs, medication usage, demographics, and surgical factors were the main independent variables of interest. A multivariate logistic regression model was used to identify independent risk factors for delayed hospital discharge after TJA.

Results:
Among 2651 TJA patients in this study, 732 (28.5%) had a length of stay of less than 2 days. The number of postoperative hypotensive events in the acute postoperative period (POD 0 and 1), defined as a systolic blood pressure less than 90 mmHg or a diastolic blood pressure less than 60 mmHg, was significantly associated with an increased length of stay (OR 1.35 [1.20, 1.53]). Patients with a higher Charlson Comorbidity Index (OR 1.77 [1.54, 2.01]), females (OR 2.13 [1.75, 2.59]), African Americans (OR 2.09 [1.68, 2.61]), the elderly (OR 1.40 [1.30, 1.51]), and patients who were not married (OR 1.98 [1.63, 2.41]), were also more likely to have an increased postoperative length of stay. Patients who stayed more than 2 days used a higher Oral Morphine Equivalent dose in the first two days, then those who stayed less than 2 days, 127 mg versus 106 mg, respectively (OR 1.11 [1.10, 1.13]).

Conclusions:
As the financial landscape of US health care is evolving, identifying means of decreasing hospital length of stay without compromising care after TJA could have a significant impact. With increased use of outpatient TJA, it is important to identify factors that may improve patient safety while reducing any potential burden from readmissions.

Thesis Cover Page

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CHAPTER 1 INTRODUCTION

Total joint arthroplasty (TJA), including both knee and hip arthroplasty, is the most frequently performed inpatient surgery in the United States, with roughly 1.2 million TJA operations in 2012 alone.[1] The current annual national healthcare expenditure for these operations is approximately 20 billion dollars, and this amount has been increasing annually.[2] One of the major drivers of the cost associated with TJA is the hospital length of stay [3] after the procedure.(Turrisi, #84) Studies examining large cohorts of patients have estimated the LOS after total knee and total hip arthroplasty to be roughly 3.5 and 3.7 days, respectively. As the financial landscape of healthcare is set to undergo significant changes, efforts aimed at decreasing LOS after TJA is one potential target to help contain and potentially decrease healthcare costs associated with these procedures.[4-7]

Multiple studies have examined factors associated with increased length of stay in the hospital after TJA.[7-12] While certain patient characteristics, such as age, body mass index (BMI), various comorbidities, race, income, and insurance status have been correlated with post-TJA LOS, fewer studies have focused on potentially modifiable clinical risk factors, such as opioid use, aberrant vital signs, or laboratory values.

Postoperative hypotension has been linked to increased LOS in other surgical fields.[13,14] While there are published clinical protocols that stress the importance of fluid management to minimize risk of postoperative hypotension after TJA, postoperative hypotension remains understudied in the orthopaedic literature.[15,16]

In this study, we analyzed inpatient hospital records for individuals undergoing primary total hip or total knee arthroplasty at a large academic medical center. We sought to identify independent modifiable risk factors for delayed discharge that have been previously underrepresented in the literature, particularly opioid use, postoperative laboratory abnormalities, and the frequency of hypotensive events. In particular we hypothesized that, similar to other surgical specialties, the number of acute postoperative hypotensive events after TJA is independently associated with prolonged LOS.

CHAPTER 2 COMPREHENSIVE REVIEW OF THE LITERATURE

Over the last century, total joint arthroplasty (TJA), including both total hip arthroplasty (THA) and total knee arthroplasty (TKA), has revolutionized the approach to treating arthritis and fractures of the hip and knee, respectively. With advances in surgery and materials science, the rates and success of THA and TKA have increased tremendously. Today, TJA, including both knee and hip arthroplasty, is the most frequently performed inpatient surgery in the United States, with roughly 1.2 million TJA operations in 2012 alone.[1] These procedures are also commonly performed all over the world, yet surgery and post-operative protocols, as well as associated cost vary greatly in different countries. One of the major drivers of cost associated with TJA is the hospital length of stay [3] after the procedure.[3] As the financial landscape of healthcare is set to undergo significant changes, efforts aimed at decreasing LOS after TJA is one potential target to help contain and potentially decrease healthcare costs associated with these procedures.[4-7] This manuscript examines the experience of one specialty orthopaedic hospital in the United States in regards to LOS after TJA, in an attempt to characterize factors that influence LOS and identify potential modifiable post-operative targets which may be addressed to reduce LOS.

HISTORY OF TOTAL JOINT REPLACEMENT

An understanding of the importance of reducing hospital LOS after TJA would be incomplete without a brief background on the history of hip and knee joint

replacement. The earliest recorded attempts were in Germany in the 1880s and 1890s, by Professor Themistocles Gluck, with dramatic improvements over the past century.

For hip arthroplasty, Professor Gluck first presented the use of ivory as a replacement for the femoral heads of patients whose native femoral heads had been destroyed by tuberculosis. Since the late 19th century, many newer materials have been tried and tested. In the 1920s, American surgeon Marius Smith-Peterson invented the first mold of an acetabular cup, a hollow smooth surface to fit over the femoral head to recreate the ball-in-socket kinematics of the hip joint. While wildly successful at first, his material of choice for the cup - glass, proved vulnerable to the stress forces experienced through the hip joint and was prone to shatter. Later, Smith-Peterson and fellow surgeon Philip Wiles developed a new cup made of stainless steel, which remains today as one material of choice, along with a polyethylene, metal, or ceramic liner.[17] [18] The femoral head component of THA has also changed over time, with metal and ceramic heads of various sizes widely used today. Each combination of femoral head and acetabular cup and liner material, including metal-on-metal, metal-on-polyethylene, and ceramic-on-ceramic, has unique advantages and disadvantages regarding loosening, wear, failure, comfort, and release of inflammatory or carcinogenic debris. The decision for material is largely surgeon dependent and occasionally patient specific.

Knee arthroplasty was also attempted by Professor Gluck using a hinged ivory joint. Drawings for his initial designs can be seen in Figure 1. While pioneering and innovative, these constructs all eventually failed due to wear properties and chronic infection[19] It was not until the principles of *reduced friction arthroplasty* first introduced to

THA in 1958 were applied to the knee, that the true potential for TKA emerged.[20] This potential came to fruition with the implant of the first bi-condylar prosthesis in 1971 as seen in Figure 2 [21] Over the last half-century, advances in prosthesis design, materials, and surgical technique, such as patellar resurfacing, and cruciate retaining or posterior stabilizing implants, have transformed TKA. Highlighting these advances, Figures 3, 4 and 5 depict modern THA and TKA prostheses.

Modern THA prosthesis generally include an acetabular cup and liner, as well as a femoral component which has a stem inserting into the proximal femur and an proximal ball to mimic the role of the femoral head. This construction aims to recreate the ball-in-socket kinematics of the hip joint. Several materials for the femoral head and liners are in use, each with different wear properties and potential benefits and drawbacks. The most common material combinations include a metal ball and polyethylene liner, ceramic ball and polyethylene liner, metal ball and metal liner, and a ceramic ball and ceramic liner.

Modern TKA prostheses generally include a femoral component made of metal and fitted to contour to the distal aspect of the femur and a tibial component which is a flat metal platform upon which rests a polyethylene spacer. Each of these components can vary depending on implant design, to best treat a wide spectrum of disease. When indicated, TKA also includes a patellar implant which is a dome-shaped piece of polyethylene cemented to the undersurface of the patella, to create a smooth articulating surface between the femoral component and patella. Some TKA prostheses involve removal of both of a patient's native cruciate ligaments, the anterior cruciciate

ligament (ACL) and the posterior cruciate ligament (PCL). These prosthesis designs are called posterior stabilizing, as they have a polyethylene component that mimics the role of a natural PCL. Other implant systems, such as the Cruciate Retaining system, involve the removal of just the ACL. The specific implant used is typically dependent on surgeon familiarity, implant innovation in design, implant cost, as well as related to patient factors. In fact, brand new implants are being tested now for TKA, such as the Bi-Cruciate Retaining implant.

With current surgical techniques and prostheses materials, a THA or TKA is expected to last 20 years, 85% of the time.[22]

Figure 1: Professor Gluck's personal drawings of his hinged Ivory Knee Joint and its Component Parts[19]

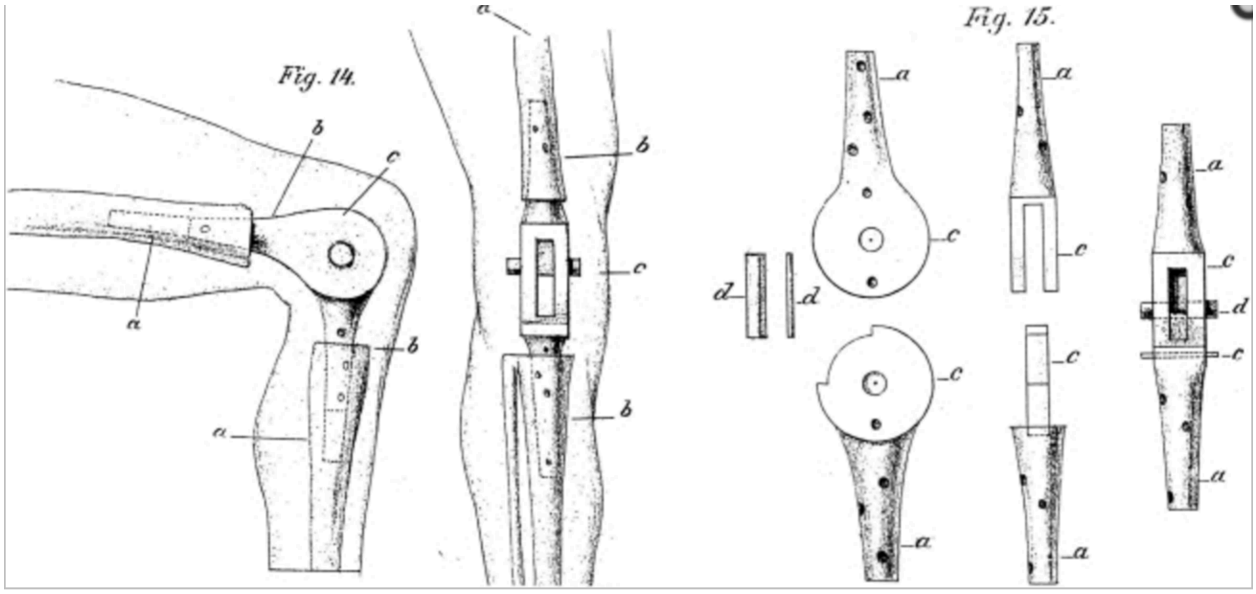


Figure 2: Anterior-Posterior and Lateral X-rays of the First Bi-Condylar Knee Arthroplasty, performed in 1971[21]

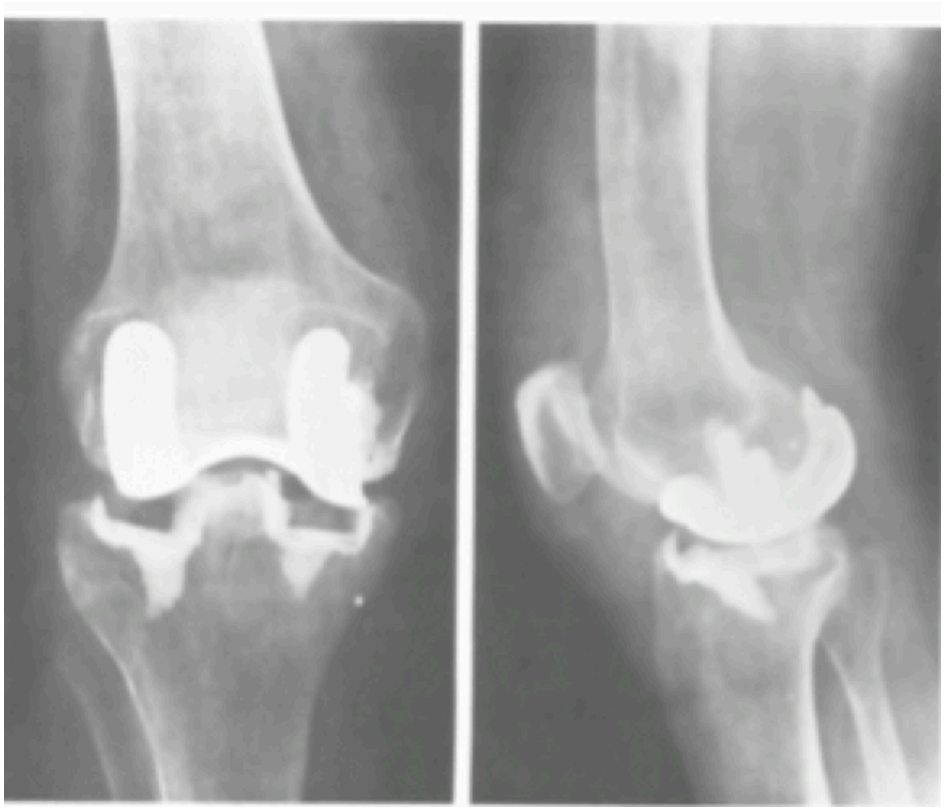


Figure 3: Individual Components of a Modern Total Hip Arthroplasty System, Merged into a Hip Replacement[23]

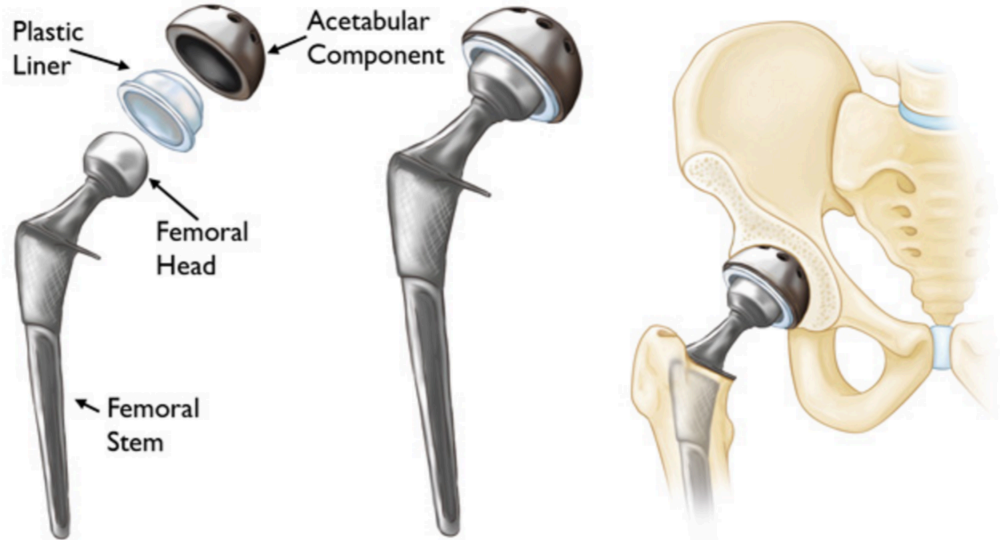


Figure 4: Components of a Modern Total Knee Arthroplasty System[24]

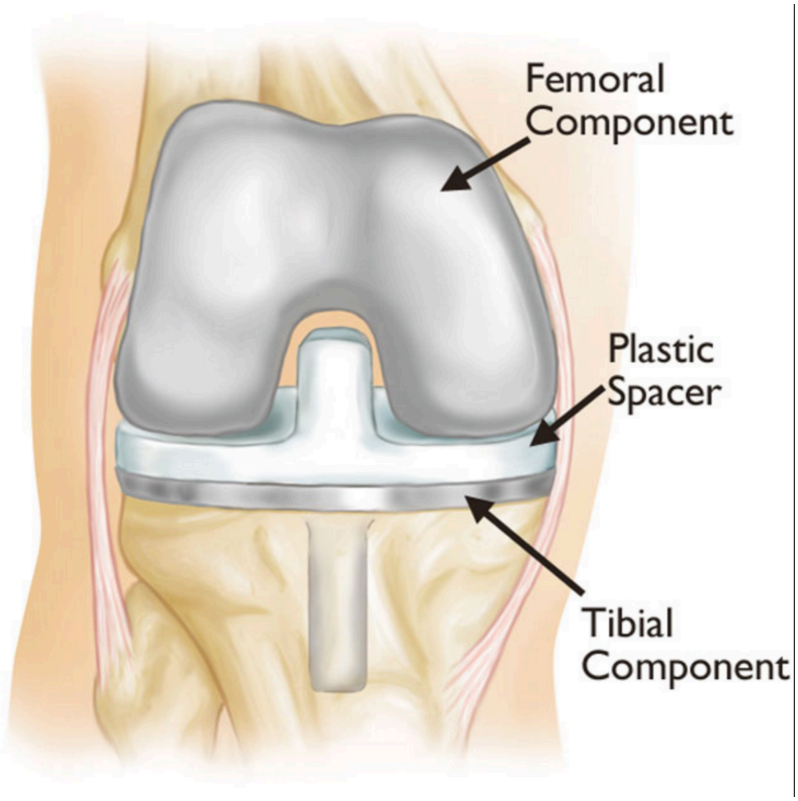
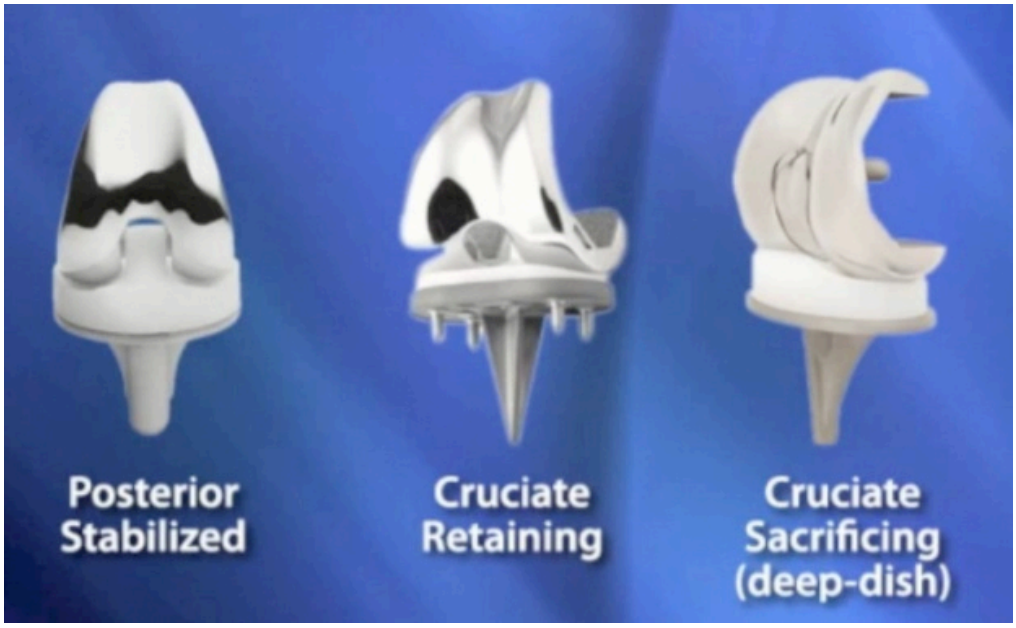


Figure 5: Components of Different Modern Total Knee Arthroplasty Systems[25]



TRENDS IN TOTAL JOINT ARTHROPLASTY NUMBERS AND COSTS

The cost of hip and knee replacements is sizable, and the projected tolls on our healthcare system are significant. While there are regional variations in price, the average price for an uncomplicated total hip replacement when considering 64 markets, was $30,124. Similarly, the average price for an uncomplicated total knee replacement procedure considering 64 markets was $31,124.[26]

More concerning than the unit cost, is the total number and rate of growth of the number of total joint replacements performed each year due to surgical advances, improved outcomes, and most importantly, an aging US demographic.

For example, the number of knee replacements more than tripled and hip replacements doubled between 1993 and 2009.[27] Over the past several years, there has been an approximate 70 percent increase in hip and knee replacements, every five years.[28] Demand for hip and knee replacements are only expected to increase as well given the ageing demographic. In addition, the obesity epidemic and need for revision arthroplasty will only add to these projections. It is projected that by 2030, the demand for primary and revision hip replacements will double, and primary and revision knee replacements will grow by at least 600%.[29] Indeed, by 2030, it is projected that the demand for hip and knee replacements will be roughly 4.5 million each year.[30]

Given these enormous numbers, it is critical to develop mechanisms to reduce the cost associated with hip and knee replacements. One of the major drivers of the cost associated with TJA is the hospital length of stay [3] after the procedure.[3] As the financial landscape of healthcare is set to undergo significant changes, efforts aimed at

decreasing LOS after TJA is one potential target to help contain and potentially decrease healthcare costs associated with these procedures.[4-7]

ADVANCES IN HOSPITAL LENGTH OF STAY

Efforts to reduce hospital length of stay have been very successful over the past two decades. These include early post-operative rehabilitation and physical therapy protocols, advances in surgery an pain management, and extensive pre-operative planning, expectation and goal setting. For example, in 1990 the varege LOS after TJA in the United States was 10 days, which dropped to 5 days by 2000. [31]

Recent studies examining large cohorts of patients in the United States have estimated the LOS after total knee and total hip arthroplasty to be roughly 3.5 and 3.7 days, respectively. Length of stay, however, varies considerably worldwide, with averages remaining as high as 8 days in the United Kingdom or even 35 days in Japan.[32,33]

Multiple studies have examined factors associated with increased length of stay in the hospital after TJA.[7-12] While certain patient characteristics, such as age, body mass index (BMI), various comorbidities, race, income, and insurance status have been correlated with post-TJA LOS, fewer studies have focused on potentially modifiable clinical risk factors, such as opioid use, aberrant vital signs, or laboratory values.

Postoperative hypotension has been linked to increased LOS in other surgical fields.[13,14] While there are published clinical protocols that stress the importance of fluid

management to minimize risk of postoperative hypotension after TJA, postoperative hypotension remains understudied in the orthopaedic literature.[15,16]

FUTURE DIRECTIONS IN TOTAL JOINT ARTHROPLASTY

Total Joint Arthroplasty has made incredible improvements to the quality of life of millions over the past century with osteoarthritis of the hip and knee. With increasing innovation in surgical techniques, materials science, nanotechnology, and operations science, the future is bright for TJA. Given the aging population, need for revision surgeries, and efforts to expand healthcare insurance to improve access to care as well as potentially lower cost of care, it is imperative to optimize modifiable variables using larger datasets and streamlined protocols to improve outcomes and reduce cost of care without compromising patient safety for patients undergoing TJA.

In this study, we analyzed inpatient hospital records for individuals undergoing primary total hip or total knee arthroplasty at a large academic medical center. We sought to identify independent modifiable risk factors for delayed discharge that have been previously underrepresented in the literature, particularly opioid use, postoperative laboratory abnormalities, and the frequency of hypotensive events. In particular we hypothesized that, similar to other surgical specialties, the number of acute postoperative hypotensive events after TJA is independently associated with prolonged LOS.

CHAPTER 3 MANUSCRIPT

TITLE:

Predictors for Delayed Discharge after Total Joint Arthroplasty of the Hip and Knee

Contribution of Student:

Ajay Premkumar led the design, data abstraction, statistical analysis, data interpretation, and write-up of this project.
As such, he will be the primary author for any journal submission of this work.

Intended journal for submission: Journal of Bone and Joint Surgery (JBJS)

The following manuscript adheres to all policies of the Journal of Bone and Joint Surgery

ABSTRACT

Background:

Total joint arthroplasty (TJA) is a common orthopaedic procedure that comprises a significant portion of US healthcare expenditures, particularly in the elderly. With the recent push towards value-based health care, predicting delays in discharge is crucial. Postoperative hypotension, a common side effect of major surgery, is a risk factor for prolonged recovery delayed discharge. While other risk factors for prolonged hospital stay have been identified in TJA patients, postoperative hypotension has been understudied in the orthopaedic literature. This study examines postoperative hypotension along with other potentially modifiable risk factors such as opioid use and laboratory anomalies and their relation to prolonged hospitalization after TJA. We hypothesize that the number of acute postoperative hypotensive events after TJA is associated with increased hospital length of stay.

Methods:

This retrospective cohort study identified 2561 primary total hip and total knee arthroplasty cases performed at a single institution between June 2012 and August 2014. We compared characteristics of cases with a hospital length of stay of less than two days to those with a hospital length of stay two days or longer. Our institution uses an accelerated physical therapy program, which may be interrupted by patient hypotension. As such, postoperative hypotension, pre and post-operative labs, medication usage, demographics, and surgical factors were the main independent

variables of interest. A multivariate logistic regression model was used to identify independent risk factors for delayed hospital discharge after TJA.

Results:

Among 2651 TJA patients in this study, 732 (28.5%) had a length of stay of less than 2 days. The number of postoperative hypotensive events in the acute postoperative period (POD 0 and 1), defined as a systolic blood pressure less than 90 mmHg or a diastolic blood pressure less than 60 mmHg, was significantly associated with an increased length of stay (OR 1.35 [1.20, 1.53]). Patients with a higher Charlson Comorbidity Index (OR 1.77 [1.54, 2.01]), females (OR 2.13 [1.75, 2.59]), African Americans (OR 2.09 [1.68, 2.61]), the elderly (OR 1.40 [1.30, 1.51]), and patients who were not married (OR 1.98 [1.63, 2.41]), were also more likely to have an increased postoperative length of stay. Patients who stayed more than 2 days used a higher Oral Morphine Equivalent dose in the first two days, then those who stayed less than 2 days, 127 mg versus 106 mg, respectively (OR 1.11 [1.10, 1.13]).

Conclusions:

As the financial landscape of US health care is evolving, identifying means of decreasing hospital length of stay without compromising care after TJA could have a significant impact. With increased use of outpatient TJA, it is important to identify factors that may improve patient safety while reducing any potential burden from readmissions.

INTRODUCTION

Total joint arthroplasty (TJA), including both knee and hip arthroplasty, is the most frequently performed inpatient surgery in the United States, with roughly 1.2 million TJA operations in 2012 alone.[1] The current annual national healthcare expenditure for these operations is approximately 20 billion dollars, and this amount has been increasing annually.[2] One of the major drivers of the cost associated with TJA is the hospital length of stay [3] after the procedure.(Turrisi, #84) Studies examining large cohorts of patients have estimated the LOS after total knee and total hip arthroplasty to be roughly 3.5 and 3.7 days, respectively. As the financial landscape of healthcare is set to undergo significant changes, efforts aimed at decreasing LOS after TJA is one potential target to help contain and potentially decrease healthcare costs associated with these procedures.[4-7]

Multiple studies have examined factors associated with increased length of stay in the hospital after TJA.[7-12] While certain patient characteristics, such as age, body mass index (BMI), various comorbidities, race, income, and insurance status have been correlated with post-TJA LOS, fewer studies have focused on potentially modifiable clinical risk factors, such as opioid use, aberrant vital signs, or laboratory values.

Postoperative hypotension has been linked to increased LOS in other surgical fields.[13,14] While there are published clinical protocols that stress the importance of fluid management to minimize risk of postoperative hypotension after TJA, postoperative hypotension remains understudied in the orthopaedic literature.[15,16]

In this study, we analyzed inpatient hospital records for individuals undergoing primary total hip or total knee arthroplasty at a large academic medical center. We sought to identify independent modifiable risk factors for delayed discharge that have been previously underrepresented in the literature, particularly opioid use, postoperative laboratory abnormalities, and the frequency of hypotensive events. In particular we hypothesized that, similar to other surgical specialties, the number of acute postoperative hypotensive events after TJA is independently associated with prolonged LOS.

METHODS

Participants

After Institutional Review Board approval, we identified all patients who underwent primary total hip or knee replacement between June 2012 and August 2014, by one of four surgeons at our institution. Each of the four surgeons is fellowship-trained and works in the same orthopaedic specialty hospital. None of the 2,561 patients identified by the above criteria died during their post-operative hospital stay, and none was subsequently excluded from our analysis.

Variables of Interest

The hypothesized predictors of prolonged LOS included patient demographics, comorbidities, inpatient opioid medication use, postoperative hypotension, and abnormal laboratory values.

Charlson Comorbidity Index (CCI) was computed as a continuous variable for each patient using International Classification of Diseases (ICD) categories.[34,35] An index score greater than 2 has been correlated to an annual mortality rate of grater than 50%.[36]

Opioid intake was converted to oral morphine equivalents [37] and recorded in milligrams (mg) as a continuous variable.(Tomei KL, #80)

The number of postoperative hypotensive events, defined as a systolic blood pressure less than 90 mmHg or a diastolic blood pressure less than 60 mmHg for any single reading, was recorded as a continuous variable for each postoperative day.[38,39]

Given the lack of universal consensus on laboratory threshold values, we determined abnormal values for laboratory results as the default threshold values used in our institution's electronic medical record system (Cerner Systems). The specific cutoffs used for each laboratory value are presented in **Appendix 1**. The presence of either an abnormal high or abnormal low value was determined for each post-operative day for each patient. Abnormal values for specific laboratory test results were thus coded as 'normal', 'abnormal high,' or 'abnormal low', for each post-operative day.

In an effort to preserve the fidelity of our model, we attempted to remove very rare abnormal lab values from our analysis. To accomplish this, if an abnormal value appeared in at least 5% of our sample, which we deemed a conservative threshold, that specific laboratory result was included in our analysis. The presence of low Calcium, high Creatinine, high Glucose, low Hemoglobin, and low Sodium values were the only laboratory results to occur at a frequency above this threshold, and thus were included in the model.

Outcomes

The primary dependent variable of interest was LOS measured as the number of days between TJA and hospital discharge. As reliable information on the exact time of discharge was not available, each night spent in the hospital after surgery was considered an increase in LOS by one day. For example, a patient discharged after spending one night in the hospital following TJA had an estimated LOS of 1 day. .

Given that 28.6%, (732/2561), of all patients had a LOS of less than 2 days, and that a LOS of 2 days was the most common duration of post-operative hospital stay, we defined prolonged LOS using the cutoff of ≥2 days.

Statistical Analysis

Statistical analysis was performed using the SAS software package version 9.4 (SAS institute Inc. Cary, NC). Student t tests were performed for continuous data and χ^2 or Fisher exact tests were performed for categorical data, as appropriate. Univariate and multivariate logistic regression was performed to identify independent risk factors for prolonged LOS. The results of logistic regression models were expressed as odds ratios (ORs) and the corresponding 95% confidence intervals (CIs) accompanied by p-values All data has been presented as aggregated data for all patients undergoing either primary total hip or total knee arthroplasty procedure in our model. Two-tailed *p* values <0.05 were considered statistically significant.

RESULTS

As shown in Table 1, the average age of patients undergoing primary TJA in this study was 62.6 (standard deviation [SD] 11.6) years, and 56.4% were women. Both the median and mode for LOS was 2 days, and 63.9% of patients were discharged before postoperative day 3 (POD 3). The mean LOS for all patients was 2.2 days (SD: 1.2, Range: 0,9) (Table 2).

Univariable Logistic Regression

Univariable analysis comparing patients with a prolonged LOS to those with a LOS of 2 days or less identified several significant associations (Table 3).

Specifically, *increased CCI score* (OR, 1.77 [CI, 1.54, 2.03]), *male sex* (OR, 2.13 [CI, 1.75, 2.59]), *non-Caucasian race* (OR, 2.09 [CI, 1.68, 2.61]), *single marital status* (OR, 1.98 [CI, 1.63, 2.41]), *increased age* (OR, 1.40 [CI, 1.30, 1.51]), *Medicaid insurance* (OR, 4.55 [CI, 2.20, 9.42]), *Medicare insurance* (OR, 3.31 [CI, 2.59, 4.23]), the number of hypotensive events on POD 0 and 1 (OR, 1.35 [CI, 1.20 1.53]), OME on POD 0 and 1 (OR, 1.11 [CI 1.10, 1.13]), and the presence of abnormally high glucose (OR, 1.36 [CI, 1.13, 1.62]) or low hemoglobin (OR, 4.64 [CI 3.84, 5.60]) on POD 0 and 1, were all significantly associated with increased LOS.

Multivariable Logistic Regression

Multivariable logistic regression analysis comparing patients with a prolonged LOS to those with a LOS of less than 2 days identified significant independent risk factors for prolonged LOS (Table 4).

After controlling for all other variables in the model (Table 4), for every five additional hypotensive readings during POD 0 and 1, there was a 20% increase in odds of a prolonged hospital LOS of greater than 2 days. Similarly, for every 10 mg increase in OME use during POD 0 and 1, the OR reflecting the association was a 14% increased odds of a LOS of 2 days or greater. Regarding non-modifiable risk factors for prolonged LOS, for every unit increase in CCI score and for every 10 year increase in age, there was a 36% and 64% increase in odds of a LOS 2 days or greater, respectively. The strongest association between any risk factor and LOS in our model was that of low hemoglobin; patients with low hemoglobin values on POD 0 or 1 had a 2.7 times odds of a LOS greater than 2 days than those without abnormal hemoglobin values on those days. When controlling for the effect of other variables in our model, the effect of Medicare and Medicaid insurance on LOS was no longer statistically significant.

Postoperative Hypotension

The number of hypotensive events during POD 0 and 1 for patients with a LOS less than 2 was compared with that of patients with a LOS greater or equal to 2, using four quartiles. Quartiles 1-4 (Q1-4) included patients with 0-1, 2-3, 4-6 and >6 hypotensive events, respectively. The sub-group analysis revealed that using Q1 as the

reference category the OR (95% CI) were 1.26 (0.99-1.59) for Q2, 1.45 (CI 1.15, 1.82) for Q3, and 1.74 (CI 1.36, 2.22) for Q4.

DISCUSSION

The post-TJA LOS in our study was 2.2 days—lower than estimates of over 3 days reported previously.[4,5] The shorter LOS observed in our patient population may be due partly to each surgeon's fellowship training, as well as the fact that TJA comprised the majority of their surgical case load during the study period. In addition, each surgeon worked in the same orthopaedic specific hospital that employs an early, aggressive physical therapy protocol and uniformly defined clinical pathways.

Our results confirm several previously identified associations.[4,5] Specifically, increased CCI score, male sex, non-Caucasian race, single marital status, and increased age were all independently associated with increased hospital LOS in our study. Of note, in crude analyses both Medicaid and Medicare enrollees had an increased LOS compared to private insurance holders; however, when adjusted for all other variables, these associations regarding insurance status and LOS were no longer statistically significant.

Our results also show that modifiable risk factors for increased hospital LOS following TJA are similar to those observed after other major surgeries.[4,5] Specifically, increased postoperative hypotensive events and opioid use during the day of surgery (POD 0) and postoperative day 1 (POD 1) were both independent risk factors for increased hospital LOS. These data supports development of clinical practices aimed at reducing early postoperative hypotension and opioid use in patients undergoing TJA.

Several laboratory values were independently associated with increased LOS, and protocols to correct these aberrant laboratory values could also prove valuable to

reduce LOS after TJA. For example, low postoperative hemoglobin was one of the strongest predictors of increased LOS. If these finding are confirmed research is needed to develop a optimal post-TJA transfusion protocol, which substantially reduce average hospital stay.

A notable strength of this study is its large sample size, which resulted in sufficient power to detect meaningful associations . Additionally, unlike national health databases with data aggregated from numerous facilities with varied protocols and surgeons with heterogeneous case loads, our patients were all treated by surgeons performing more than 400 TJA procedures each year using the same protocols.

Our study also has some limitations; as all patient information was derived from medical records, not all variables of interest, such as the presence of orthostatic hypotension or time of first postoperative physical therapy session, were recorded uniformly and thus were not included in our model. Our study employs a conservative threshold to define hypotension as any reading with a systolic pressure of 90 mmHg or less or a diastolic pressure of 60 mmHg or less, as defined previously in the literature.[38,39] It is possible that values above this threshold may also be abnormal on the continuum of postoperative blood pressure, especially in the setting of a patient with known hypertension, a common comorbidity in elderly patients undergoing TJA. Future studies should examine individual postoperative hypotension readings as a continuous variable and adjust for preoperative values and operative variables to determine the most appropriate threshold to be classified as abnormal in this clinical setting. Lastly, laboratory values were coded as abnormal low, normal, or abnormal

high as described above. The categorical presence of abnormal low or high values was thus ascertained and included in our model; however, our model does not consider the magnitude of laboratory derangements. As this study was intended to be an initial examination to identify potentially modifiable risk factors for prolonged hospital LOS, we deemed our handling of laboratory values as appropriate; however, future work should explore each abnormal value and its magnitude in addition to its direction, to further guide initiatives aimed at reducing aberrant values and potentially reducing hospital LOS.

In conclusion, as the financial landscape of US health care is rapidly evolving, identifying means of decreasing hospital length of stay without compromising care after TJA could have a significant impact. This study demonstrates that increased opioid use, hypotensive events, and abnormal calcium, hemoglobin, creatinine, and glucose values in the acute postoperative period are all independently associated with a longer hospital LOS after TJA. It is important to identify these and other potentially modifiable factors that may improve patient safety while reducing readmissions.

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TABLES and FIGURES:

Table 1. Demographic and clinical characteristics of the study cohort

TABLE 1. Demographic and Clinical Characteristics of the Study Cohort		
	Class	*mean ± sd [min, max]* *freq/total(%)*
Age (years)		62.6 ± 11.6 [16.0 , 94.0]
OME (mg); first 2 days		190.6 ± 140.0 [0, 2623]
Sex	Female	1445/2561 (56.4%)
	Male	1116/2561 (43.6%)
Race	White	1900/2561 (74.2%)
	Non-White	661/2561 (25.8%)
Marital status	Married	1697/2561 (66.3%)
	Not Married	864/2561 (33.7%)
CCI score	0	1703/2561 (66.5%)
	1	561/2561 (21.9%)
	2	185/2561 (7.2%)
	3	77/2561 (3.0%)
	4	22/2561 (0.9%)
	5	9/2561 (0.4%)
	6	2/2561 (0.1%)
	7	1/2561 (0.0%)
	8	1/2561 (0.0%)
Pre-op Diagnosis	Osteoarthritis	2311/2557 (90.4%)
	Other	246/2557 (9.6%)
Insurance	HMO / Managed Care	884/2552 (34.6%)
	Medicaid	69/2552 (2.7%)
	Medicare	1172/2552 (45.9%)
	Other	427/2552 (16.7%)
Calcium – Low		1156/2561 (45.1%)
Creatinine – High		1803/2561 (70.45)
Glucose – High		1414/2561 (55.2%)
Hemoglobin – Low		1872/2561 (73.1%)
Sodium – Low		1109/2561 (43.3%)

Table 2. Distribution of the Hospital Length of Stay

TABLE 2. Hospital Length of Stay (LOS)		
		mean ± sd [Min, Max] *freq/total (%)*
LOS (days), continuous measure		2 ± 1 [0 , 9]
LOS (days), ordinal measure	0	1/2561 (0.0%)
	1	731/2561 (28.5%)
	2	954/2561 (37.3%)
	3	603/2561 (23.5%)
	4	156/2561 (6.1%)
	5	63/2561 (2.5%)
	6	23/2561 (0.9%)
	7	23/2561 (0.9%)
	8	2/2561 (0.1%)
	9	5/2561 (0.2%)
LOS (days), categorical measure	≥ 2 days	1829/2561 (71.4%)
	< 2 days	732/2561 (28.6%)

Table 3: Univariable Logistic Regression for Predictors of Delayed Discharge

TABLE 3. Univariable Logistic Regression for Predictors of Delayed Discharge; <2 days vs ≥ 2 days					
		LOS ≥ 2 days (n=1829)	*LOS <2 days (n=732)*	*OR (95% CI)*	*P-value*
Hypotensive events *POD 0 & 1*		4.08 (4.29)	3.23 (3.45)	1.354 (1.196, 1.532)	<0.01
CCI Score		0.58 (0.86)	0.28 (0.61)	1.768 (1.543, 2.025)	<0.01
Sex	Female	1150/1829 (62.9%)	295/732 (40.3%)	2.129 (1.753 , 2.585)	<0.01
	Male	679/1829 (37.1%)	437/732 (59.7%)	1	
Race	White	1289/1829 (70..5%)	611/702 (87.0%)	1	<0.01
	Non-White	540/1829 (29.5%)	121/732 (16.5%)	0.478 (0.383, 0.595)	
Marital status	Married	1137/1829 (62.2%)	560/732 (76.5%)	0.505 (0.415, 0.614)	<0.01
	Not Married	692/1829 (37.8%)	172/732 (23.5%)	1	
Age*		63.89 (11.70)	59.36 (10.68)	1.40 (1.30, 1.51)	<0.01
OME (mg)*		216.49 (151.53)	125.48 (72.70)	1.11 (1.10, 1.13)	<0.01
Pre-op Diagnosis	Osteoarthritis	1652/1825 (90.5%)	659/732 (90.0%)	1.03 (0.77, 1.38)	0.83
	Other	173/1825 (9.5%)	73/732 (10%)	1	
Insurance	HMO/Managed Care	542/1823 (29.7%)	342/729 (46.9%)	1.10 (0.87, 1.39)	<0.01
	Medicaid	60/1823 (3.3%)	9/729 (1.2%)	4.55 (2.20, 9.42)	
	Medicare	969/1823 (53.2%)	203/729 (27.9%)	3.31 (2.59, 4.23)	
	Other	252/1823 (13.8%)	175/729 (24.0%)	1	
Low Calcium		844/1829 (46.25)	312/732 (42.6%)	1.15 (0.97, 1.37)	0.11
High Creatinine		1271/1829 (69.5%)	532/732 (72.7%)	0.85 (0.70, 1.03)	0.10
High Glucose		1050/1829 (57.4%)	364/732 (49.7%)	1.36 (1.14, 1.62)	0.00
Low Hemoglobin		1506/1829 (82.3%)	366/732 (50.0%)	4.64 (3.84, 5.60)	<0.01
Low Sodium		801/1829 (43.8%)	308/732 (42.1%)	1.08 (0.90, 1.28)	0.41
** variables presented as mean ± sd*					

Table 4. Multivariable Logistic Regression for Predictors of Delayed Discharge

TABLE 4. Multivariable Logistic Regression for Predictors of Delayed Discharge*			
Parameter	*OR*	*95% CI*	*P-Value*
Intercept			
Hypotensive events on POD 0 & 1 (Per 5 additional hypotensive events)	1.20	(1.02, 1.40)	0.03
CCI score (per 1 unit increase)	1.36	(1.15, 1.59)	<0.01
Sex (Female vs Male)	0.72	(0.56, 0.93)	0.01
Race(White vs Non-White)	0.56	(0.43, 0.74)	<0.01
Age (per 10 year increase)	1.64	(1.42, 1.88)	<0.01
Marital status(married vs not married)	0.68	(0.53, 0.88)	<0.01
OME (mg) (per 10 mg increase)	1.14	(1.12, 1.16)	<0.01
Pre-op DX (osteoarthritis v. other)	1.00	(0.66, 1.51)	1.00
Insurance			<0.01
HMO/Managed Care v. Other	0.83	(0.62, 1.11)	
Medicaid v. Other	2.04	(0.87, 4.78)	
Medicare v. Other	1.43	(1.00, 2.02)	
Low Calcium	1.29	(0.98, 1.70)	0.07
High Creatinine	0.37	(0.25, 0.54)	<0.01
High Glucose	1.88	(1.39, 2.55)	<0.01
Low Hemoglobin	2.70	(2.09, 3.49)	<0.01
Low Sodium	0.93	(0.71, 1.22)	0.60
** CCI as a continuous variable*			

Table 5. Hypotensive Events Days 0-1, by quartile vs. LOS

TABLE 5. Hypotensive Events Days 0-1, by quartile vs. LOS				
	LOS ≥ 2 days Freq/Total (%)	*LOS < 2 days Freq/Total (%)*	*OR (95% CI)*	*P-value*
Hypotensive Events (Days 0-1)				
Q4: >6	417/1829 (22.8%)	122/732 (16.7%)	1.74 (1.36 , 2.22)	<0.01
Q3: >3 - ≤6	429/1829 (23.5%)	151/732 (20.6%)	1.45 (1.15, 1.82)	
Q2: >1 - ≤ 3	391/1829 (21.4%)	158/732 (21.6%)	1.26 (0.99 , 1.59)	
Q1: ≤ 1	592/1829 (32.4%)	301/732 (41.1%)	1	

Appendix 1. Laboratory threshold values

APPENDIX 1. Laboratory Reference Ranges		
	Low*	High*
Albumin	3.5	5
Alkaline Phosphatase	38	126
Anion Gap	2	12
Osmolality, Calculated	261	280
Bilirubin, Total	0.2	1.3
Calcium, Total	8.4	10.5
Chloride	98	107
Carbon Dioxide	22	30
Creatinine	0.66	1.25
Glucose	74	106
Potassium	3.5	5.1
Protein, Total	6.3	8.2
Aspartate Aminotransferase	15	46
Alanine Aminotransferase	21	72
Sodium	137	145
Blood Urea Nitrogen	9	20
Hemoglobin	11.4	16.1
Hematocrit	33.3	46.5
** to be classified as low or high, value must be below or above cut-off*		

CONCLUSION AND RECOMMENDATIONS

Over the last century, total joint arthroplasty (TJA), including both total hip arthroplasty (THA) and total knee arthroplasty (TKA), has revolutionized the approach to treating arthritis and fractures of the hip and knee, respectively. With advances in surgery and materials science have transformed TJA into one of the most successful surgical procedures available. As such, TJA is the most frequently performed inpatient surgery in the United States, with roughly 1.2 million TJA operations in 2012 alone.[1] These procedures are also commonly performed all over the world, yet surgery and post-operative protocols, as well as associated cost vary greatly in different countries.

While they bring significant improves on patients' quality of life, the cost of hip and knee replacements is sizable, and the projected tolls on our healthcare system are significant. While there are regional variations in price, the average price for an uncomplicated total hip replacement when considering 64 markets, was $30,124. Similarly, the average price for an uncomplicated total knee replacement procedure considering 64 markets was $31,124.[26]

More concerning than the unit cost, is the total number and rate of growth of the number of total joint replacements performed each year due to surgical advances, improved outcomes, and most importantly, an aging US demographic.

For example, the number of knee replacements more than tripled and hip replacements doubled between 1993 and 2009.[27] Over the past several years, there has been an approximate 70 percent increase in hip and knee replacements, every five years.[28] Demand for hip and knee replacements are only expected to increase as well

given the ageing demographic. In addition, the obesity epidemic and need for revision arthroplasty will only add to these projections. It is projected that by 2030, the demand for primary and revision hip replacements will double, and primary and revision knee replacements will grow by at least 600%.[29] Indeed, by 2030, it is projected that the demand for hip and knee replacements will be roughly 4.5 million each year.[30]

Given these enormous numbers, it is critical to develop mechanisms to reduce the cost associated with hip and knee replacements. One of the major drivers of the cost associated with TJA is the hospital length of stay [3] after the procedure.[3] As the financial landscape of healthcare is set to undergo significant changes, efforts aimed at decreasing LOS after TJA is one potential target to help contain and potentially decrease healthcare costs associated with these procedures.[4-7]

Efforts to reduce hospital length of stay have been very successful over the past two decades. These include early post-operative rehabilitation and physical therapy protocols, advances in surgery and pain management, and extensive pre-operative planning, expectation and goal setting. For example, in 1990 the average LOS after TJA in the United States was 10 days, which dropped to 5 days by 2000.[31]

The post-TJA LOS in our study was 2.2 days—lower than estimates of over 3 days reported previously.[4,5] The shorter LOS observed in our patient population may be due partly to each surgeon's fellowship training, as well as the fact that TJA comprised the majority of their surgical case load during the study period. In addition, each surgeon worked in the same orthopaedic specific hospital that employs an early, aggressive physical therapy protocol and uniformly defined clinical pathways.

While certain patient characteristics, such as age, body mass index (BMI), various comorbidities, race, income, and insurance status have been correlated with post-TJA LOS, fewer studies have focused on potentially modifiable clinical risk factors, such as opioid use, aberrant vital signs, or laboratory values.

Our results confirm several previously identified associations.[4,5] Specifically, increased CCI score, male sex, non-Caucasian race, single marital status, and increased age were all independently associated with increased hospital LOS in our study. Of note, in crude analyses both Medicaid and Medicare enrollees had an increased LOS compared to private insurance holders; however, when adjusted for all other variables, these associations regarding insurance status and LOS were no longer statistically significant.

Our results also show that modifiable risk factors for increased hospital LOS following TJA are similar to those observed after other major surgeries.[4,5] Specifically, increased postoperative hypotensive events and opioid use during the day of surgery (POD 0) and postoperative day 1 (POD 1) were both independent risk factors for increased hospital LOS. These data supports development of clinical practices aimed at reducing early postoperative hypotension and opioid use in patients undergoing TJA.

Several laboratory values were independently associated with increased LOS, and protocols to correct these aberrant laboratory values could also prove valuable to reduce LOS after TJA. For example, low postoperative hemoglobin was one of the strongest predictors of increased LOS. If these finding are confirmed research is needed

to develop a optimal post-TJA transfusion protocol, which substantially reduce average hospital stay.

As the financial landscape of US health care is rapidly evolving, identifying means of decreasing hospital length of stay without compromising care after TJA could have a significant impact. This study demonstrates that increased opioid use, hypotensive events, and abnormal calcium, hemoglobin, creatinine, and glucose values in the acute postoperative period are all independently associated with a longer hospital LOS after TJA. It is important to identify these and other potentially modifiable factors that may improve patient safety while reducing readmissions after TJA.