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Hospital Volume as a Source of Variation for Major Complications and Early In-Hospital Mortality After Total Joint Arthroplasty

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ABSTRACT

Background: Although the effects of hospital volume on mortality have been studied in other procedures, data on total joint arthroplasty (TJA) are limited. Furthermore, mortality rate among surgical patients with early major complications has become an important patient safety indicator and has been shown to be an important driver of mortality in certain operations. Our objective was to examine the effect of hospital volume on early complications and in-hospital mortality rate after TJA.

Material and methods: A total of 5,396,644 patients undergoing elective, unilateral TJA between 2002 and 2011 were identified using the Nationwide Inpatient Sample database. Hospitals were divided by annual volume into tertiles. Major complications associated with postoperative mortality were identified. Risk-adjusted mortality (RAM) was calculated to adjust for hospital case mix.

Results: For THAs performed at high-volume centers, RAM was significantly lower (0.03% vs 0.41%, $P < .05$, high vs low volume) with lower prevalence of major complications (2.2% vs 3.3%, $P < .05$, high vs low volume). We observed similar results for TKA where RAM was lower (<0.01% vs 0.06%, $P < .05$, high vs low volume). Major complications, however, were not significant (1.4% vs 1.5%, $P < .83$). Pneumonia was the most prevalent complication for THA (1.5% vs 0.9%, $P < .05$, high vs low volume) and TKA (0.9% vs 0.5%, $P < .05$ high vs low volume).

Conclusion: Hospital volume appears to drive a large proportion of the variation in early in-hospital mortality after TJA. This variation does not seem to be explained by hospital case mix and rather by the higher prevalence of major postoperative complications in lower volume institutions.

Introduction

Total hip (THA) and knee arthroplasties (TKA) have proven to be clinically effective procedures with excellent survivability in the long term and significant improvements in pain, function, and health-related quality of life [1-4]. Over the next few decades, the number of hip and knee arthroplasty procedures is projected to rise to over 4 million annually [5].

Major early complications and in-hospital mortality are low-incidence events in elective total joint arthroplasty (TJA) [6]. However, considering the current and projected high volumes of these procedures, determining modifiable risk factors for these adverse events may have dramatic effects on patient outcomes and, most importantly, survivability. Furthermore, mortality rate among surgical patients with major treatable complications has become an important patient safety indicator known as failure to rescue, which has been shown to be an important driver of mortality in certain operations [7]. Higher hospital volume has been associated with lower risk of mortality, lower risk of readmission, and higher likelihood of being discharged home [8]. Other studies have proposed an association between higher hospital volume and lower rates of revision, complications, and mortality [8-11]. Many of these studies, however, were regional evaluations with smaller population cohorts.

The objectives of our study were to examine the effect of hospital volume on (1) major early treatable complications that can

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lead to mortality as well as (2) in-hospital mortality itself after elective unilateral THA and TKA using a nationwide database given the low incidence of these events. Our hypothesis was that higher volume hospitals had less mortality from major complications (failure to rescue) than lower volume hospitals.

Material and methods

Using the Agency for Healthcare Research and Quality Nationwide Inpatient Sample (NIS) database, we conducted a retrospective, cross-sectional study to examine specific major complications and mortality after primary THA and TKA. The NIS is a stratified, statistically valid survey of hospitals conducted by the federal Healthcare Cost and Utilization Project [12] and is the largest publicly available all-payer inpatient care database in the United States. Hospitals are randomly selected to achieve an approximately 20% representative sample of all US nonfederal hospitals. Sampling weights are provided to produce the national estimates. All discharge records from each of the selected hospitals are collected and form part of the NIS file for a given year. Because of the large size of the database, the NIS is particularly well suited for epidemiological studies related to specific procedures or diseases in the national population [13,14].

International Classification of Disease Clinical Modification version 9 procedure codes and NIS variables were used to identify all patients undergoing elective, unilateral primary THA and TKA (International Classification of Disease Clinical Modification version 9 procedure code 81.51 and 81.54). Major postoperative treatable complications were identified based on Agency for Healthcare Research and Quality specifications for Patient Safety Indicator number 4 (death rate among surgical inpatients with serious treatable complications) also known as failure to rescue [15]. These complications included pneumonia, pulmonary embolism (PE)/deep vein thrombosis, sepsis, shock/cardiac arrest, and gastrointestinal bleeding. Mortality was coded within the NIS and was risk-adjusted (RAM) to account for hospital case mix. Our risk-adjustment model included age, gender, procedure (THA and TKA), and comorbidities based on Elixhauser index which is part of the NIS [16]. Hospitals were divided by annual volume into tertiles (Fig. 1).

A total of 5,396,644 patients undergoing elective, unilateral TJA between 2002 and 2011 were identified. The average age was 66 years ±11 SD, 61% were female, and 69% underwent TKA. Major treatable complications as well as mortality were compared between low-volume and high-volume hospitals. As per the NIS data use agreement, any time the observations (ie, individual records) in any given cell of tabulated data were less than or equal to 10, they were not individually reported but instead summarized as "≤10" [17]. All statistical analyses were performed using SPSS version 21 for Mac (IBM Corp., Armonk, NY). Descriptive statistics were calculated for all variables used within the study. There were few missing values (less than 1%) for all variables used; cases with missing values were skipped for the purpose of this analysis. Pearson chi-square was used to compare variables. Statistical significance was assigned at $P < .05$.

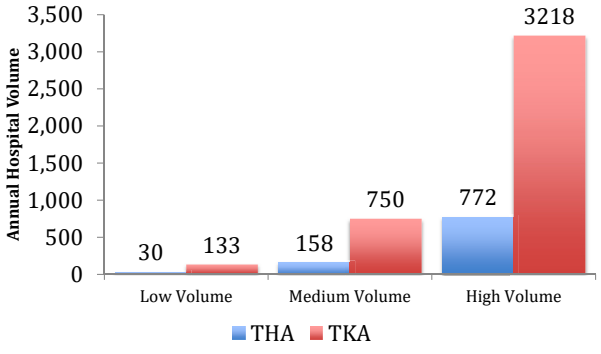

Figure 1. Annual hospital volume by tertile and procedure.

Results

Hospitals were categorized as high volume when performing 772 THAs per year or more or low volume when preforming 30 THAs per year or less. For TKA, high-volume centers were those performing 3218 procedures per year or more, and low-volume centers were those performing 133 procedures per year or less.

High-volume hospitals had a lower prevalence of major treatable complications (2.2% vs 3.3%, $P < .05$) by individual categories (Table 1), as well as less postoperative mortality than low-volume hospitals, even after controlling for case mix (0.03% vs 0.41%, $P < .05$).

For hospitals performing TKA, those performing over 3218 procedures a year had lower mortality rate after controlling for case mix (<0.01% vs 0.06%, $P < .05$) and higher prevalence of pneumonia and PE/deep vein thrombosis than hospitals with less than 150 procedures annually (Table 2).

Of the major complications, pneumonia was the most prevalent one in THA (1.5% vs 0.9%, $P < .05$, high vs low volume) and TKA (0.9% vs 0.5%, $P < .05$, high vs low volume).

Discussion

We aimed to examine the effect of hospital volume on (1) major early treatable complications that can lead to mortality as well as (2) in-hospital mortality itself after elective unilateral THA and TKA using a nationwide database given the low incidence of these events. Our hypothesis was that higher volume hospitals had less mortality from major complications (failure to rescue) than lower volume hospitals. We found that hospital volume appears to drive a large proportion of the variation in early in-hospital mortality after TJA. This variation does not seem to be explained by hospital case mix and rather by the higher prevalence of major postoperative complications in lower volume institutions.

The cohort evaluated in this study showed a correlation between hospital volume and major complications as well as mortality. The highest volume centers showed significantly lower complication rates than the lowest volume hospitals for elective THA. There was no difference in complication rate in elective TKA

Table 1
Comparison by hospital volume of mortality and major complications after total hip arthroplasty.

Characteristics	Low volume, n = 695	Medium volume, n = 695	High volume, n = 697
Mean volume/y	30	158	772[b]
Observed mortality	0.18%	0.15%	0.11%
Risk-adjusted mortality	0.41%	0.06%	0.03%[b]
Complications[a]	3.37%	2.94%	2.23%[b]
Pneumonia	1.57%	1.48%	0.99%[b]
PE/DVT	0.34%	0.45%	0.43%
Sepsis	0.10%	0.14%	0.08%
Shock/Cardiac arrest	0.22%	0.25%	0.17%
GI bleeding	1.24%	0.79%	0.67%[b]

DVT, deep vein thrombosis; GI, gastrointestinal bleeding.
[a] Complications based on Agency of Healthcare Research and Quality (AHRQ) Patient Safety Indicator 4 (PSI-4).
[b] Comparison between high- and low-volume hospitals, $P < .05$.

Table 2
Comparison by hospital volume of mortality and major complications after total knee arthroplasty.

Characteristics	Low volume, n = 743	Medium volume, n = 744	High volume, n = 744
Mean volume/y	133	750	3218[b]
Observed mortality	0.67%	0.52%	0.49%
Risk-adjusted mortality	0.06	<0.01	<0.01[b]
Complications[a]	1.59%	1.52%	1.43%
Pneumonia	0.93%	0.70%	0.55%[b]
PE/DVT	0.24%	0.39%	0.50%[b]
Sepsis	0.05%	0.05%	0.03%
Shock/Cardiac arrest	0.11%	0.07%	0.07%
GI bleeding	0.34%	0.39%	0.36%

DVT, deep vein thrombosis; GI, gastrointestinal bleeding.
[a] Complications based on Agency of Healthcare Research and Quality (AHRQ) Patient Safety Indicator 4 (PSI-4).
[b] Comparison between high- and low-volume hospitals, $P < .05$.

patients. Differences in pneumonia in both the hip and knee cohorts contributed most to the elevated complication rate discovered. A statistically significant difference in RAM was recognized in both THA and TKA.

Although the relationship between hospital volume and the rates of mortality and complications has been explored, the data are limited. Singh et al. [9] examined a regional database to determine the effect hospital volume had on the complication and mortality rate in hip and knee arthroplasty patients at 30 days and 1 year. A significant difference in 1-year mortality was observed in hip arthroplasty patients showing a lower rate in higher volume centers. A significant difference in 1-year mortality in knee arthroplasty patients was not observed. This study was unable to show a significant difference in overall complications and mortality at 30 days for both hip and knee arthroplasties. However, a significant difference in venous thromboembolism was observed showing lower rates in the highest volume centers. This was not the case with our present study where complications were elevated in lower volume hospitals except for thromboembolism.

The NIS database has been used to evaluate the RAM in THA patients. Doro et al. [10] evaluated 275,813 primary hip arthroplasty patients (1988-2000) and found a significant trend in decreasing inpatient mortality in higher volume hospitals. These data were supported by our present study, showing significant differences in mortality not only in elective hip arthroplasty but also in knee arthroplasty procedures.

Bozic et al. [8] in a study of 182,146 patients from 312 hospitals showed that mortality and complication differences between hospitals can be explained by differences in hospital protocols, quality-improving initiatives, and adherence to evidence-based practices. They evaluated how often Surgical Care Improvement Project guidelines related to lower extremity arthroplasty were missed during the care of hip and knee arthroplasty patients. Their study showed a correlation between failure to adhere to these process guidelines and complications including mortality. They showed that lower volume hospitals had more difficulty in consistently adhering to these care path measures.

Although complication rates appear to be a significant driver of overall mortality, the ability to rescue (avoid mortality from complications) plays an integral role when these complications do occur. In surgical patients, Ghaferi et al. [7] showed that when hospitals were stratified based on mortality rate, there was no significant difference in the complication rate. One hypothesis is that the difference in mortality observed in our study between high- and low-volume institutions may not completely be due to complication rate, but rather their ability to resuscitate patients after complications occur.

This study has several limitations inherent to the analysis of large administrative databases such as the NIS. Incomplete data collection, uncertain compliance and accuracy of coding related to diagnosis and procedures performed, and lack of detailed clinical information are all valid concerns. However, administratively coded comorbidities and complications have been shown to correlate reasonably well with the clinical medical record with acceptable accuracy [18]. We are also limited in what data are available for analysis; for example, cause of death is not available, which may underestimate the true prevalence of cardiac complications and thromboembolic events such as PE. These recognized limitations are inherent to all studies using this database design and could potentially be improved through prospective data collection. The NIS also includes in-hospital events only, and any complications or deaths that occur after discharge would not be captured in this database.

Hospital volume appears to drive a large proportion of the variation in early in-hospital mortality after TJA. This variation does not seem to be explained by hospital case mix and rather by the higher prevalence of major early postoperative complications in lower volume institutions. Our results offer some insight into the relationship between hospital volume and inpatient complication and mortality rates following TJA.

Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: J. A. Browne receives royalties from DJO Surgical; is a paid consultant for DJO Surgical and OsteoRemedies; is an unpaid consultant for and has stock or stock options in Radlink; receives financial or material support from Elsevier, *Journal of Arthroplasty*, and JBJS; is in the editorial or governing board of *Journal of Arthroplasty*; and is a board member in AAHKS, AAOS, and SOA. M. R. D'Apuzzo is a paid consultant for Zimmer Biomet and is a board member in AAOS and MOA.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.03.003.

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