■ ARTHROPLASTY

Do higher-volume hospitals provide better value in revision hip and knee arthroplasty?

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Aims

The purpose of this study is to determine if higher volume hospitals have lower costs in revision hip and knee arthroplasty.

Materials and Methods

We questioned the Centres for Medicare and Medicaid Services (CMS) Inpatient Charge Data and identified 789 hospitals performing a total of 29 580 revision arthroplasties in 2014. Centres were dichotomised into high-volume (performing over 50 revision cases per year) and low-volume. Mean total hospital-specific charges and inpatient payments were obtained from the database and stratified based on Diagnosis Related Group (DRG) codes. Patient satisfaction scores were obtained from the multiyear CMS Hospital Compare database.

Results

High-volume hospitals comprised 178 (30%) of the total but performed 15 068 (51%) of all revision cases, including 509 of 522 (98%) of the most complex DRG 466 cases. While high-volume hospitals had higher Medicare inpatient payments for DRG 467 ($21 458 *versus* $20 632, p = 0.038) and DRG 468 ($17 003 *versus* $16 120, p = 0.011), there was no difference in hospital specific charges between the groups. Higher-volume facilities had a better CMS hospital star rating (3.63 *versus* 3.35, p < 0.001). When controlling for hospital geographic and demographic factors, high-volume revision hospitals are less likely to be in the upper quartile of inpatient Medicare costs for DRG 467 (odds ratio (OR) 0.593, 95% confidence intervals (CI) 0.374 to 0.941, p = 0.026) and DRG 468 (OR 0.451, 95% CI 0.297 to 0.687, p < 0.001).

Conclusion

While a high-volume hospital is less likely to be a high cost outlier, the higher mean Medicare reimbursements at these facilities may be due to increased case complexity. Further study should focus on measures for cost savings in revision total joint arthroplasties.

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In 2015, the United States spent $605.9 billion on Medicare benefits for 55 million individuals and is forecast to spend $5.4 trillion annually on health care by 2024.[1,2] In 2007, the United States Medicare program spent an estimated $7.3 billion on care for patients with osteoarthritis, rendering it the single most expensive condition covered by Medicare that year.[3-5] In Canada, the population of patients with osteoarthritis grew from 2.9 million to 3.6 million between 2003 and 2010.[6] More than 80 000 total hip arthroplasties (THAs) are performed annually in the United Kingdom, with an estimated cost of £64 million for primary procedures alone.[7] These statistics represent only a sample of what is a clear trend toward increased use of arthroplasty surgery for populations worldwide.

Alongside the increasing number of primary arthroplasties performed, the number of revision THA and total knee arthroplasty (TKA) procedures are projected to increase markedly.[8,9] Concurrently, as technology, surgical techniques and peri-operative management continue to improve, patients are being offered primary arthroplasty at a younger age and this is reflected in the data on revision arthroplasty. According to a study in the United States, using the Nationwide Inpatient Sample database, in 2006, 40% of revision THA patients and 44% of revision TKA patients were younger than 65

years old and this younger age group is expected to make up 50% of all revision arthroplasty procedures by 2030.[10]

Managing the growth in revision procedures represents a different challenge from addressing that of primary arthroplasty. It has been well documented that revisions are associated with higher use of healthcare resources and higher costs than primary procedures.[11-16] Furthermore, revisions are more challenging technically and historically and have inferior clinical outcomes compared with primary interventions.[12,13,17] Primary THAs and TKAs performed in hospitals that perform a higher volume of procedures are associated with a lower risk of complications and subsequent revision surgery, but it is not known whether the same holds true for revision arthroplasty.[18-24] The purpose of this study is to determine if higher volume centres have lower costs than low-volume hospitals in revision hip and knee arthroplasty. Secondarily, we assessed any independent risk factors for hospitals having high episodes of care costs in revision THAs and TKAs.

Materials and Methods

We examined the Centres for Medicare and Medicaid Services (CMS) Hospital Compare database, which included data from 4788 hospitals participating in Medicare across the United States.[25] We then accessed the Medicare Provider Utilisation and Payment Data Inpatient Charge Data for 2014. This database includes cost data for over 3000 hospitals that receive Medicare Inpatient Prospective Payment System (IPPS) payments for using the Medicare Severity Diagnosis Related Group (MS-DRG) for 2014.[26] Hospitals with less than 11 DRG episodes during the year are excluded from the dataset. The MS-DRGs in the database represent over seven million patients and include over 75% of total Medicare IPPS discharges.[26] We identified all hospitals with data from patients in DRG 466, 467 and 468 (revision of hip or knee arthroplasty, with and without major comorbidities or complications) from the Inpatient Charge Data and cross-referenced the Hospital Compare database using each hospital's unique Medicare provider identity. This study was exempt from Institutional Review Board approval.

Hospitals were designated as urban if they resided in an urban ZIP code designated by the 2010 United States Census (area greater than 50 000 people).[27] Hospitals were also noted as being from a lower socioeconomic area if the median household income of the ZIP code was in the bottom quintile ($21 432) nationally.[28] Low-volume revision hospitals were defined as performing fewer than 50 total cases falling under DRG 466, 467 or 468 in 2014.

We recorded the mean hospital-specific charge data and mean Medicare payment data for each institution. Mean total payments included all payments for the index inpatient stay, in this study: the MS-DRG amount, bill total per day, beneficiary primary payer claim payment amount, beneficiary Part A co-insurance amount, beneficiary deductible amount, beneficiary blood deducible amount and DRG outlier amount.[26]

The Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) is a patient satisfaction survey required by all hospitals in the United States. Data from each of the qualifying hospitals in the study were obtained from the Hospital Compare Dataset including star rating (out of five) and linear rating (out of 100) based upon responses given by patients. The patients rate the quality of communication from physicians and nurses, the responsiveness of staff and whether they would recommend the hospital to others.[25] HCAHPS scores for the hospitals in this study were collected by CMS from 1 October 2014 to 30 September 2015.

Of the 4788 hospitals in the Hospital Compare Database, 3999 hospitals were excluded from the Inpatient Charge Dataset, as they performed fewer than ten procedures falling within the DRGs of interest during the months of the study period.[29] Of the remaining 789 hospitals with data available for inclusion in the study, there were 178 (23%) higher-volume hospitals and 611 (77%) lower-volume revision hospitals. Within these hospitals, a total of 29 580 revision hip and knee arthroplasty procedures were performed during the period of the study in 2014 (11 to 45 cases per hospital). DRG 466, which represents the most complex revision procedures and those patients with the most comorbidities, accounted for 522 (2%) of the total. A total of 17 135 (58%) were DRG 467 revision procedures of intermediate complexity/comorbidity and the remaining 11 923 (40%) were DRG 468 revision procedures without major complications or comorbidities. The mean CMS overall hospital star rating was 3.41 (SD 0.77), while the mean overall HCAHPS summary rating was 3.14 (SD 0.67). CMS has previously outlined the methodology that they used to calculate complications and re-admission scores for THA and TKA.[30]

Statistical analysis. We first compared the means of continuous variables including hospital-specific charges, total payments and Medicare payments between the higher volume and lower volume revision groups using an independent samples *t*-test. We chose to analyse results separately by DRG group as the complexity and cost of cases varies greatly in revision arthroplasty. HCAHPS scores between the two groups were also compared using an independent samples *t*-test. Categorical variables were analysed using a chi-squared test, except where expected or observed variables were < 5, in which case Fisher's exact test was used. Statistical significance was set at a p-value < 0.05. To control for other confounding hospital demographic and geographic factors, we performed a multivariable logistic regression analysis to determine independent risk factors for a hospital being in the upper quartile of inpatient Medicare payments for the most common revision procedure group, DRG 467 (greater than $22 791).

Results

Of all the hospitals, 178 (30%) were classified as high-volume and performed 15 068 (51%) of all revisions. High-volume-centres also performed the vast majority of the

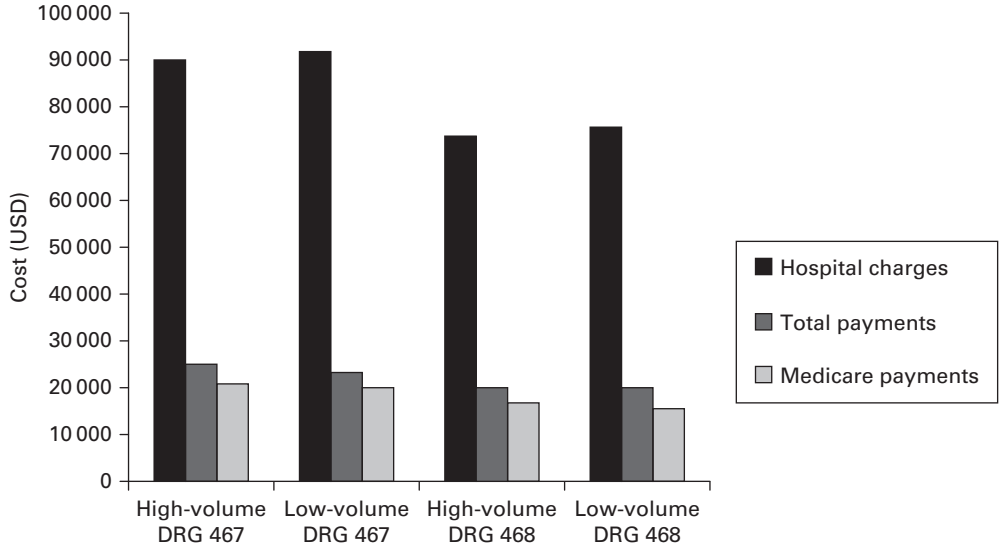

Fig. 1

Comparison of mean hospital charges, total payments and Medicare payments among high- and low-volume hospitals in revision total hip and knee arthroplasty. All costs are in United States dollars (USD) (DRG, Diagnosis Related Group).

Table I. Comparison of charges and payments between high- and low-volume revision arthroplasty hospitals

Variable	High-volume (n = 178)	Low-volume (n = 611)	p-value
DRG 466 Hospitals (n)	33	1	
Mean covered charges (SD)	$143 473 ($53 667)	$141 843 (NA)	0.976
Mean total payments (SD)	$38 287 ($10 440)	$30 802 (NA)	0.485
Mean Medicare payments (SD)	$38 287 ($10 440)	$30 802 (NA)	0.485
DRG 467 Hospitals (n)	178	487	
Mean covered charges (SD)	$90 743 ($37 770)	$91 842 ($41 353)	0.756
Mean total payments (SD)	$24 971 ($5353)	$23 381 ($4786)	< 0.001
Mean Medicare payments (SD)	$21 458 ($4693)	$20 632 ($4489)	0.038
DRG 468 Hospitals (n)	163	345	
Mean covered charges (SD)	$74 308 ($31 729)	$76 185 ($35 019)	0.562
Mean total payments (SD)	$20 488 ($4526)	$19 283 ($3855)	0.002
Mean Medicare payments (SD)	$17 003 ($4214)	$16 120 ($3354)	0.011

DRG 466, DRG 467 and DRG 468, revision of hip or knee arthroplasty with and without major comorbidities or complications
High-volume centres are defined as ≥ 50 revisions per year; low-volume centres are defined as < 50 revisions per year.
All costs are given in United States Dollars
All p-values tested using independent samples *t*-test
DRG, Diagnosis Related Group; NA, not applicable

most complex procedures, DRG 466 cases (509 of 522, 98%). While high-volume hospitals had higher Medicare inpatient payments for DRG 467 ($21 458 *versus* $20 632, *t*-test, p = 0.038) and DRG 468 ($17 003 *versus* $16 120, *t*-test, p = 0.011), there was no difference in hospital-specific charges between the groups (Fig. 1, Table I). The highest charges were associated with DRG 466, but there was no significant difference between high- and low-volume hospitals ($143 473 *versus* $141 843, *t*-test, p = 0.976). However, only one low-volume hospital reported DRG 466 cases. As a continuous variable, there was a weak but statistically significant linear relationship with case volume and mean Medicare inpatient payments for DRG 467 (R^2 = 0.011, multivariate linear regression, p = 0.020).

Higher-volume facilities had a higher mean CMS hospital star rating (3.63 *versus* 3.35, *t*-test, p < 0.001) compared with lower-volume centres (Tables II and III). When controlling for hospital geographic and demographic factors, high-volume revision hospitals are less likely to be in the upper quartile of inpatient Medicare costs for DRG 467 (odds ratio (OR) 0.593, 95% confidence intervals (CI) 0.374 to 0.941, p = 0.026) and DRG 468 (OR 0.451, 95% CI 0.297 to 0.687, p < 0.001) (Tables IV and V).

Discussion

Revision THA and TKA are known to be more costly and have less predictable outcomes than primary procedures.[11-17,31] As the burden of revision surgery increases, attention has been turned towards efforts to improve cost and patient outcomes.[32-36] Clearly, one of the challenges inherent with revision THA and TKA is that the appropriate treatment often varies by aetiology.[11,34,35,37] As the complexity

Table II. Comparative analysis of hospital demographics and outcomes of high-volume revision arthroplasty centres and lower volume institutions

Variable	High-volume (n = 178)	Low-volume (n = 611)	p-value
Mean CMS overall star rating (SD)	3.63 (0.71)	3.35 (0.71)	< 0.001
Mean risk-adjusted complication score (SD)	2.81 (0.65)	3.00 (0.62)	0.001
Mean risk-adjusted re-admission score (SD)	4.36 (0.67)	4.60 (0.63)	< 0.001
Geographic area, n (%)			
Northeast	26 (*14*)	90 (*15*)	0.410
Midwest	46 (*26*)	168 (*27*)	0.410
South	78 (*44*)	230 (*37*)	0.410
West	28 (*16*)	123 (*20*)	0.410
Hospital in urban ZIP code, n (%)	150 (*99*)	530 (*93*)	0.002
Hospital in low-SES ZIP code, n (%)	6 (*3*)	18 (*3*)	0.627

High-volume centres are defined as ≥ 50 revisions per year; low-volume centres are defined as < 50 revisions per year
All p-values tested using independent samples *t*-test
CMS, Centres for Medicare and Medicaid Services; SES, socioeconomic status

Table III. Patient satisfaction results from the Hospital Consumer Assessment of Healthcare Providers and Systems survey comparing higher volume revision arthroplasty hospitals with lower volume hospitals

Variable	High-volume (n = 178)	Low-volume (n = 611)	p-value
Recommend hospital: linear mean score (SD)	91.1 (2.7)	89.3 (3.2)	< 0.001
Recommend hospital: star rating, mean (SD)	3.26 (0.63)	3.11 (0.68)	0.007
Doctor communication: linear mean score (SD)	91.8 (1.5)	91.4 (1.5)	0.004
Doctor communication: star rating, mean (SD)	3.22 (0.78)	3.00 (0.83)	0.002
Nurse communication: linear mean score (SD)	91.6 (1.4)	91.0 (1.9)	< 0.001
Nurse communication: star rating, mean (SD)	3.65 (0.65)	3.42 (0.74)	< 0.001
Staff responsiveness: linear mean score (SD)	84.6 (2.8)	84.2 (3.2)	0.174
Staff responsiveness: star rating, mean (SD)	3.05 (0.72)	2.96 (0.77)	0.176
Overall hospital rating: Linear mean score (SD)	90.0 (2.2)	89.0 (2.4)	< 0.001
HCAHPS summary: Star rating, mean (SD)	3.26 (0.63)	3.11 (0.68)	0.007

High-volume centres are defined as ≥ 50 revisions per year; low-volume centres are defined as < 50 revisions per year
All p-values tested using independent samples *t*-test
HCAHPS, Hospital Consumer Assessment of Healthcare Providers and Systems

increases, so too does the direct cost of treatment.[15,38] Revision arthroplasty patients tend to be less healthy than primary patients,[13,17] have higher complications,[16,39] increased mortality,[17,39] increased frequency of discharge to a facility other than home[13,16,39] and increased re-admission rates, all of which increase the costs involved.[13,31,39]

Katz et al[40] noted that 64% of revision arthroplasties performed were at the same hospital as the index arthroplasty. A total of 74% of revision arthroplasties were performed in hospitals with the same hospital volume category as the hospital where the primary procedure was performed, while 16% were performed at higher volume hospitals.[40] In another report, the same authors found that 49% of all revisions were performed in centres in which ten or fewer of these procedures were carried out annually, but higher volume centres performed 14% more revisions than they generated.[41] Of all the hospitals reviewed in this study, 30% were classified as high volume, performing over 50 revisions per year. Those high-volume centres performed 51% of all revision arthroplasties and 98% of cases with major comorbidities and complications. Performing complex revisions at higher volume centres may have benefits both to the patients and to the healthcare system as a whole.

Previous work also suggests substantial variability in cost and outcomes based on region and hospital setting (i.e. teaching, non-teaching, urban, rural, volume).[17,42,43] While high-volume hospitals in our study had higher Medicare inpatient payments for DRG 467 ($21 458 *versus* $20 632) and DRG 468 ($17 003 *versus* $16 120), there was no difference in hospital-specific charges between the groups. Burns et al[44] determined that revision TKA was 65% as cost effective as primary TKA in relation to improvement in terms of increased patient-reported outcome measures (revisions being 1.56 times more expensive than primary procedures per ten point increase in the Western Ontario and McMaster Universities Osteoarthritis Index).[44,45] Barrack et al[15] demonstrated that for revision THA, complex cases had a significantly higher hospital charge of $51 290 compared with simple cases ($34 328). Both volume and complexity of revisions increased during the study period.[15]

Worldwide, the most common causes for revision TKA are aseptic loosening (29.8%), infection (14.8%) and pain

Table IV. Multivariable analysis of hospital demographic factors for Medicare payments in the upper quartile of all hospitals for Diagnosis Related Group 467

Risk factor	Odds ratio	95% CI	p-value
50 or more revision TJAs	0.593	0.374 to 0.941	0.026
100 or more revision TJAs	1.751	0.744 to 4.121	0.200
Urban hospital	0.675	0.338 to 1.348	0.266
Northeast region	1.392	0.829 to 2.337	0.211
Midwest region	0.454	0.290 to 0.711	0.001
South region	0.296	0.192 to 0.457	< 0.001
Lower socioeconomic area	0.970	0.386 to 2.440	0.948

All p-values tested using independent samples *t*-test
CI, confidence interval; TJA, total joint arthroplasty

Table V. Multivariable analysis of hospital demographic factors for Medicare payments in the upper quartile of all hospitals for Diagnosis Related Group 468

Risk factor	Odds ratio	95% CI	p-value
50 or more revision TJAs	0.451	0.297 to 0.687	< 0.001
100 or more revision TJAs	0.990	0.432 to 2.266	0.980
Urban hospital	1.202	0.612 to 2.360	0.593
Northeast region	1.660	0.965 to 2.856	0.067
Midwest region	0.756	0.486 to 1.117	0.216
South region	0.540	0.356 to 0.819	0.540
Lower socioeconomic area	0.945	0.409 to 2.188	0.896

All p-values tested using independent samples *t*-test
CI, confidence interval; TJA, total joint arthroplasty

(9.5%).[9] Failure of TKA requiring revision is multifactorial, including patient-specific characteristics, surgical technique and implant-related factors.[9] A study of Canadian data demonstrated an increased mortality rate (6.8%) and an increase in use of healthcare resources in frail patients compared with those who were more healthy.[46] The cost of revision is related to the aetiology: Kurtz et al[11] estimated the cost of a primary THA and TKA to be $30 300 and $24 200 respectively (2009 figures), while revision THA and TKA for prosthetic joint infection incurred costs of $93 600 and $74 900 respectively. When comparing surgical options for infection after THA in Australia, Merollini et al[47] demonstrated comparable cost ramifications. Costs were $13 187 for a single debridement, $27 006 for a one-stage revision, $42 772 for a two-stage revision and $70 381 for a failed two-stage revision.[47] The increased financial burden associated with performing revision arthroplasty, particularly in the case of complex revisions, creates a challenge for payers and policy makers and warrants further study.

Higher hospital volumes have been associated with lower risk of complications following primary THA[18,19] and TKA.[20-24] We found that high-volume centres performed 98% of the complex revisions and had a better mean CMS star rating. There are conflicting reports for the outcomes of revision arthroplasty at high-volume centres *versus* low-volume centres. Katz et al[41] found a less striking association with volume and outcome following revision surgery compared with primary, although they found a lower rate of dislocation for those patients treated in hospitals performing more than 50 revisions per year. Taylor et al[48] noted lower inpatient and 30-day mortality in both revision THA and revision TKA in high-volume centres (performing > 25 cases per year) compared with low-volume centres. Feinglass et al[49] reported an overall complication rate of 7.3% with medium-volume hospitals (seven to 14 cases per year) having higher complication rates, but no difference between low- and high-volume centres. Doro et al[19] reported the mean length of stay in low-volume centres was 8.48 days compared with 7.04 days in very high-volume centres (defined as being in the highest quartile). In-hospital mortality was 0.48% in very high-volume centres compared with 1.2% in low-volume ($p < 0.001$). There was also a trend toward decreased discharge to extended care facility in very high-volume centres (60%), compared with low-volume centres (68%). While higher volume centres may have the potential to improve outcomes, the correlation with outcome and cost is less clear. With the shift towards value-based reimbursement, it is uncertain what the future economics of revision arthroplasty will look like.

There are several limitations to this study. The use of Medicare data does not allow for detailed analysis of financial data. Namely, it is impossible to accurately discern actual hospital cost from submitted hospital charges. We do not have access to patient-specific or provider-specific financial data. As such, we can only rely on reimbursement

and hospital-specific charges as a proxy for cost. Importantly, from a healthcare policy position, payments made by CMS represent the cost of providing these services to the system. The use of claims data specifically may underestimate or overestimate patient factors and surgical complexity as case-specific data are unavailable for more in-depth analysis. While we can broadly categorise complexity based on coding, as mentioned above, codes may not be accurate and the spectrum of complexity seen in revision surgery is not easily captured by simple codes. While we cannot give specific complication and re-admission percentage rates for each hospital, CMS does assign risk-adjusted complication and re-admission scores specific to primary THA and TKA. We defined high volume as ≥ 50 revisions per year and it is acknowledged that adjustments to this definition could affect the results. Furthermore, CMS excludes patients with ten or fewer DRG procedures in their data sets, so we are unable to analyse results from the centres with the lowest volumes. Additionally, the CMS dataset analyses only hospital level data, which is not specific to each provider in the system. Surgeon-specific volume offers another mechanism for addressing the issue of volume that we believe is worthy of further investigation. HCAHPS data and satisfaction scores include all hospitals and all conditions, therefore are not specific to revision arthroplasties.

In conclusion, hospitals which perform over 50 revision arthroplasties per year have higher patient satisfaction scores than low-volume centres. While a high-volume hospital is less likely to be a high-cost outlier, the higher mean Medicare reimbursements at these facilities may be a result of increased case complexity. Further study is needed to identify measures for cost savings in revision THA and TKA.

Take home message:

- High volume hospitals tend to be less of a cost outlier in joint arthroplasty surgery.

- Higher mean Medicare reimbursement at high-volume hospitals may be the result of increased case complexity.

Author contributions:
N. B. Frisch: Reviewing the literature, Writing the manuscript, Revising the manuscript, Statistical analysis.
P. M. Courtney: Reviewing the literature, Writing the manuscript, Revising the manuscript, Statistical analysis.
B. Darrith: Reviewing the literature, Writing the manuscript, Revising the manuscript.
C. J. Della Valle: Reviewing the literature, Writing the manuscript, Revising the manuscript.

The study was exempt from Institutional Review Board approval.

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