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Are complication rates for elective primary total hip arthroplasty in Ontario related to surgeon and hospital volumes? A preliminary investigation

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Objective: To test the hypothesis that complication rates for elective total hip replacement operations are related to surgeon and hospital volumes.

Design: Retrospective population cohort study.

Study cohort: Patients who had undergone elective total hip replacement in Ontario during 1992 as captured in the Canadian Institute for Health Information database.

Main outcome measures: In-hospital complications, 1- and 3-year revision rates, 1- and 3-year infection rates, length of hospital stay, and 3-month and 1-year death rates.

Results: Surgeons with patient volumes above the 80th percentile (more than 27 hip replacements annually) discharged patients approximately 2.4 days earlier ($p < 0.05$) than surgeons with volumes below the 40th percentile (less than 9 hip replacements annually) even after adjusting for discharge disposition, hospital volume, patient age, sex, comorbidity and diagnosis. Complication rates requiring hospital readmission and death rates did not differ by surgeon or hospital volume ($p > 0.05$).

Conclusions: There is no evidence to support regionalization of elective hip replacement surgery in Ontario based on adverse clinical outcomes. Surgeons who perform a large number of total hip replacements are discharging patients earlier than less experienced surgeons, without any demonstrable increase in complications leading to hospital readmission. The explanation for this observation remains unknown and will require further study.

Objectif : Vérifier l'hypothèse selon laquelle il y a un lien entre les taux de complications à la suite d'arthroplasties électives totales de la hanche et les volumes des chirurgiens et de l'hôpital.

Conception : Étude rétrospective de cohortes.

Cohorte d'étude : Patients qui ont subi une arthroplastie élective totale de la hanche en Ontario en 1992 selon la base de données de l'Institut canadien d'information sur la santé.

Principales mesures de résultats : Complications à l'hôpital, taux de révision à un et trois ans, taux d'infection à un et trois ans, durée de l'hospitalisation et taux de mortalité à trois mois et à un an.

Résultats : Les chirurgiens dont le volume de patients dépassait le 80^{e} percentile (plus de 27 arthroplasties de la hanche par année) ont renvoyé leurs patients environ 2,4 jours plus tôt ($p < 0,05$) que les

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chirurgiens dont les volumes n'atteignaient pas le 40e percentile (moins de neuf arthroplasties de la hanche par année) même après rajustement pour les modalités du congé, le volume de l'hôpital, l'âge du patient, le sexe, la comorbidité et le diagnostic. Les taux de complications qui ont entraîné une nouvelle hospitalisation et les taux de mortalité ne différaient pas selon le chirurgien ou le volume de l'hôpital ($p > 0,05$).

CONCLUSIONS : Il n'y a pas de données probantes qui appuient la régionalisation de l'arthroplastie élective de la hanche en Ontario en fonction de résultats cliniques indésirables. Les chirurgiens qui réalisent un nombre important d'arthroplasties totales de la hanche libèrent leurs patients plus rapidement que les chirurgiens moins chevronnés, sans que cela augmente de façon démontrable les complications qui entraînent une nouvelle hospitalisation. L'explication de cette observation demeure inconnue et il faudra l'étudier plus à fond.

There is considerable evidence in the literature to suggest that a patient's outcome after surgery is partly related to the experience of the hospital and the surgeon caring for that patient.[1–11] Some have suggested that patient complications could be minimized by assigning certain procedures, including total hip arthroplasty, to regional centres of excellence.[7,8,10] Hospital and surgeon experience with total hip arthroplasty might conceivably affect patient outcome in several ways. Experienced providers might make more appropriate decisions regarding the indications for surgery and other operative details as they gain technical expertise and learn which factors result in better patient outcomes. Moreover, rehabilitation and other important ancillary services may be more readily available to the high-volume providers. With large numbers of similar cases, both hospitals and surgeons may develop routines that minimize the risk of errors in management.

High-volume providers in both academic centres[12] and the community[13] have reported excellent results for total hip arthroplasty. A recent study of elective total hip replacement operations performed in the state of Washington revealed that low-volume surgeons experienced a significantly higher rate of complications, including surgical complications, infection, revision and mortality.[5] To the best of our knowledge, Canadian data have not previously been examined for the purpose of relating provider volumes to outcome after total hip arthroplasty.

Purpose

The purpose of this study was to evaluate the relationship between provider (hospital and surgeon) volume and the rate of complications for elective total hip arthroplasty in Ontario. Specifically our aims were to describe surgeon and hospital volume distributions for total hip replacement operations in the province, and to analyse case mix-adjusted surgical morbidity and death rates as a function of surgeon and hospital volume.

Methods

Study cohort selection

The Canadian Institute for Health Information (CIHI) database was used for this study. The dataset is restricted to inpatient admissions and includes surgeon, hospital and encrypted patient identifiers as well as Canadian Classification of Procedures (CCP) codes[14] and International Classification of Diseases, ninth revision (ICD-9-CM)[15] diagnostic codes. All inpatient admissions within Ontario are captured within the CIHI dataset, enabling patients to be tracked across different hospitals and physicians (essentially limiting loss to follow-up to only those patients leaving the province). Some information regarding the hospital admission and patient demographics is also available. Each hospital assigns a unique code to every surgeon who operates at that facility. Unfortunately it is not possible to link surgeons across hospitals. Thus, if a surgeon moves from one institution to another or has multiple hospital privileges he or she shows up multiple times in the CIHI dataset. To minimize this problem, we chose to study a single year.

A cohort of patients who had undergone elective total hip replacement operations during 1992 was identified by an algorithm designed to include only patients with inflammatory or degenerative arthritis who underwent elective total hip replacement. Surgeon and hospital volumes were computed by counting all hip replacement operations (without applying any exclusion criteria) for the same year. Descriptive statistics for surgeon and hospital volumes were then computed to divide providers into 5 equal groups based on the 20th, 40th, 60th and 80th percentiles. Because of the small number of patients treated by surgeons in the lower percentile groups, the bottom and middle 2 groups were combined. Surgeons and hospitals were thus grouped together into low- (below the 40th percentile), medium- (40th to 80th percentile) and high- (above the 80th percentile) volume groups based on the number of hip replacements performed during 1992. Serious complications during the index admission were documented as a binary variable (no major complications versus 1 or more major complications). Only codes for such diagnoses related to accidental surgical mishaps, myocardial infarction, stroke, etc., were included in the definition. No attempt was made to evaluate "softer" events such as post-

operative anemia in order to minimize coding inaccuracies for conditions subject to wide interpretation.[16] The patient cohort was followed for 3 years during which time revision hip surgery and admissions for hip infections were sought. Joint dislocations after hip arthroplasty were not included in the final analysis because the low incidence of this complication precludes comparisons across provider volume groups.

The cohort of hip replacement patients was then linked to the Ontario mortality file to obtain accurate information regarding patient deaths as the CIHI dataset captures only in-hospital deaths.

CIHI patient file linkages over time were performed, based on the patient's health card number. This unique identifier is reliably recorded in the CIHI dataset only after approximately July 1991, thus limiting the years available for analysis.

All reported statistics were adjusted for age, comorbidity,[17,18] gender and surgical diagnosis (inflammatory or noninflammatory arthritis).

Analysis of data

Data were analysed using SPSS version 5.0 on a desktop personal computer.[19] For each patient the occurrence or absence of infection and revision at 1 and 3 years from the time of index admission were recorded. Death status was similarly evaluated at 3 months and 1 year, as well as during the initial hospitalization. Length of hospital stay was evaluated as a continuous outcome variable. Ordinary linear or logistic regression requires that all observations be statistically independent of each other. This assumption was violated in our data since multiple patients received care by the same hospital or surgeon provider. For this reason, generalized estimating equations suitable for correlated data were applied using an SAS macro,[20] running under SAS version 6.11 for personal computers. Interactions between covariates, surgeon volume and hospital volume were individually tested for every model. The interaction term between hospital and surgeon volume was also evaluated by entering it into the model after all main effects had been included. None of the interaction terms were found to reach statistical significance. For clarity and to maximize degrees of freedom, only the main effects model data are presented.

Results

Surgeon and hospital volume

During 1992, 329 surgeons performed one or more elective primary total hip arthroplasties in 1 of 90 different hospitals. The number of patients treated by each group of surgeons and hospitals is shown in Table I. The volume calculations include all of the hip replacements that providers managed (without any exclusion criteria).

Study cohort

Of the 6550 patient records that contained the CCP codes 81.51 or 81.59 in 1992, 3645 unique patients met all of the entry criteria.

Table II depicts patient characteristics as well as the unadjusted rates of various complications by provider volume group. Note that the comparison of complication rates across provider volume groups in Table II may be significantly biased since no adjustment has been made to account for differences in case mix.

Mortality (index procedure and cumulative mortality at 3 months and 1 year)

Thirteen patients (0.4%) died during the initial elective hospitalization. This number was too small to establish adequate levels of significance for comparing provider volume groups. Patient age and comorbidity were significantly ($p < 0.05$) related to the probability of dying during the initial hospitalization after elective total hip arthroplasty (Table III).

Twenty-six patients (0.7%) died within 3 months and 61 patients (1.7%) died within 1 year after the initial hip replacement operation. Surgeon and hospital volume was not significantly related to patient mortality ($p > 0.05$) (Tables II and III). Patient comorbidity was significantly ($p < 0.05$) associated with the risk of dying within 3 months of hip replacement surgery. Comorbidity, age and male sex were significantly ($p < 0.05$) associated with 1-year mortality.

Table I

Characteristics of Surgeon and Hospital Volume Groups

	Surgeon volume			Hospital volume		
Variable	Low	Medium	High	Low	Medium	High
Percentile	< 40	40–80	> 80	< 40	40–80	> 80
No. of providers	142	122	65	38	34	18
No. patients/yr	< 9	9–27	> 27	< 42	42–107	> 107
Total no. of patients	289	1269	2087	474	1471	1700
Mean hospital volume	75.8	75.2	172.5			
Mean surgeon volume				16.2	32.2	78.2

Infection (cumulative incidence at 1 year and at 3 years)

Thirty-five patients (1.0%) were readmitted at least once for an infection involving a hip joint prosthesis during the first year after elective total hip arthroplasty. Seventy patients (1.9%) experienced an infection within 3 years of the initial operation. Surgeon and hospital volumes were not significantly ($p > 0.05$) related to the likelihood of an infection.

Revision (cumulative incidence at 1 year and at 3 years)

Forty-four patients (1.2%) were admitted within 1 year of the index operation for a revision procedure. There were 80 admissions for revision within 3 years of the index operation (2.2%). Surgeon and hospital volume, age, comorbidity, gender and diagnosis were not significantly ($p > 0.05$) related to the risk of revision.

Complications (during index hospitalization)

During the initial index procedure, 319 patients (8.8%) sustained a serious complication. Patient age, comorbidity and a diagnosis other than osteoarthritis were significantly ($p < 0.05$) related to such events (Table III). Surgeon and hospital volumes were not significantly ($p > 0.05$) related to complication rates.

Length of hospital stay

Surgeon volume as well as age, comorbidity, gender and diagnosis were related significantly ($p < 0.05$) to patient length of hospital stay after elective total hip replacement (Table IV). The hospital stay for patients treated by the lowest-volume surgeons (less than 9 patients treated per year) averaged approximately 2.4 days longer ($p < 0.05$) than the highest-volume surgeons (more than 27 patients treated per year), even after adjusting for patient age, gender, comorbidity, diagnosis and discharge disposition. Hospital volume was not related to patient length of stay after elective total hip arthroplasty.

Table II

Unadjusted Patient Characteristics by Provider Group*

	Surgeon volume			Hospital volume		
Variable	Low	Medium	High	Low	Medium	High
Mean age, yr	67.6	68.1	66.0†	69.0	67.8	65.5†
Comorbidity > 0, %	19.4	16.6	17.1	19.2	17.4	16.3
Comorbidity > 2, %	7.3	5.0	5.0	5.1	5.8	4.6
Males, %	41.2	42.2	42.0	42.0	43.6	40.6
No osteoarthritis, %	10.4	7.0	7.5	7.0	6.6	8.6
Discharged home, %	36.3	43.0	33.5†	45.4	41.3	31.8†
Mean hospital stay, d	13.6	12.3	11.0†	12.8	11.6	11.4†
Died during index hospitalization, %	0.3	0.4	0.3	0.4	0.3	0.4
Died within 3 mo, %	1.0	0.7	0.7	0.6	0.7	0.8
Died within 1 yr, %	2.4	2.0	1.4	2.1	1.8	1.4
Infection within 3 yr, %	2.8	2.2	1.6	2.5	1.8	1.8
Infection within 1 yr, %	1.4	1.1	0.8	1.1	1.1	0.8
Revision within 3 yr, %	3.5	1.9	2.2	1.5	2.0	2.5
Revision within 1 yr, %	1.4	1.1	1.2	0.6	1.2	1.4†
Complications during index hospitalization, %	6.9	8.7	9.0	6.8	9.2	8.9
Deep vein thrombosis within 3 mo, %	3.5	3.5	3.3	2.3	3.0	3.9‡
Urinary tract infection during index hospitalization, %	2.4	3.0	2.7	4.4	3.2	1.9†

*Statistical comparisons were made by the Kruskal–Wallis one-way analysis of variance or the Pearson χ^2 test, depending on whether the variable of interest represented a continuous quantity (comparison of mean values across groups) or a dichotomous variable (comparison of the percentage of positive cases across groups).
†$p \leq 0.01$
‡$0.01 < p < 0.05$

Discussion

Others have suggested that the results of total hip arthroplasty may improve with surgeon experience.[21–24] A population study from the state of Washington evaluated the relationship between surgeon volume and complication rates in that state.[5] The provider volume distributions in that state differed markedly from those in Ontario. Washington surgeons at the 40th percentile for hip replacement volume averaged fewer than 2 hip replacements annually, whereas the equivalent cutoff for Ontario surgeons fell at 9 hip replacements. Washington surgeons at the 80th percentile averaged more than 10 hip replacements annually, whereas Ontario surgeons in the same percentile group replaced more than 27 hips annually (Table I). We attempted to apply the 3 absolute volume groups used in the Washington study to the Ontario situation (i.e., fewer than 2 hip replacements, 2 to 10

hip replacements, and more than 10 replacements). Unfortunately, most of the hip surgeons in Ontario fell into the highest Washington volume group, leaving too few patients in the other volume groups for valid statistical analysis. Similarly, hospital volumes in Ontario tended to be much higher than those in the state of Washington.

Dataset limitations precluded evaluation of long-term revision rates and other long-term outcomes in both the Washington and the Ontario studies. Both studies did consider short-term revision rates, which could be computed from the administrative data. Although short-term results are of less interest when comparing implant designs, early postoperative results represent an important end point in the context of provider experience. We reasoned that a revision (for noninfectious causes) within 3 years of an elective primary total hip arthroplasty would often be due to technical difficulties potentially incurred at the time of initial operation due to provider inexperience.

As a group, Washington surgeons performing fewer than 2 hip replacements annually were found to have significantly higher early revision rates, infection rates and 3-month death rates, even after adjusting for hospital volume, patient age, comorbidity, gender and surgical diagnosis.[5] We were unable to demonstrate a significant relationship between surgeon volume and complication rates in Ontario; however, the differences in volume distribution between the 2 regions must be kept in mind. In Ontario, we noted that patients treated by low-volume surgeons had a significantly longer stay in hospital, even after adjusting for discharge disposition, hospital volume, patient age, gender, comorbidity and surgical diagnosis. A similar trend was noted in the Washington study.[5] It seems that high-volume surgeons have mechanisms in place that allow patients to be discharged more rapidly, independent of discharge disposition (such as transfer to a rehabilitation hospital). Moreover, the earlier discharge does not appear to be associated with an increased frequency of adverse events requiring readmission to hospital.

Regionalization of certain surgical procedures, including total hip replacement, has been recommended

Table III

Adjusted Complication Rates by Provider Volume

	Complication*						
	Readmission for hip infection		Readmission for hip revision		Patient death		
Variable†	≤ 3yr	≤ 1 yr	≤ 3yr	≤ 1 yr	≤ 3 mo	≤ 1 yr	Complications during admission
Surgeon volume							
< 9 v. > 27	1.7 (0.7, 4.2)	1.7 (0.5, 5.9)	2.1 (1.0, 4.5)	1.4 (0.4, 4.8)	1.9 (0.4, 10.2)	1.6 (0.6, 4.6)	0.8 (0.5, 1.3)
9–27 v. > 27	1.4 (0.8, 2.5)	1.3 (0.6, 2.9)	1.1 (0.6, 2.0)	1.1 (0.5, 2.3)	1.3 (0.4, 3.8)	1.3 (0.6, 2.6)	1.0 (0.7, 1.3)
Hospital volume							
< 42 v. > 107	1.1 (0.5, 2.3)	1.1 (0.4, 3.2)	0.5 (0.2, 1.2)	0.4 (0.1, 1.8)	0.5 (0.1, 2.7)	1.0 (0.4, 2.6)	0.7 (0.4, 1.2)
42–107 v. > 107	0.9 (0.5, 1.5)	1.2 (0.6, 2.6)	0.8 (0.4, 1.3)	0.9 (0.4, 1.9)	0.7 (0.2, 2.1)	1.0 (0.5, 2.1)	1.0 (0.7, 1.4)
Patient age, /10 yr	0.9 (0.9, 1.0)	0.9 (0.8, 1.0)	1.0 (1.0,1.0)	1.0 (0.9, 1.0)	1.4 (0.9, 2.3)	1.9 (1.4, 2.6)	1.3 (1.3, 1.3)
Patient comorbidity, 1 v. 0	1.2 (0.7, 2.2)	1.1 (0.5, 2.5)	0.9 (0.5, 1.7)	0.8 (0.4, 2.0)	4.0 (1.8, 8.8)	2.8 (1.6, 4.9)	1.8 (1.3, 2.4)
Patient diagnosis, OA v. non-OA	0.7 (0.4, 1.3)	0.7 (0.3, 1.8)	1.0 (0.5, 2.0)	0.6 (0.3, 1.4)	1.1 (0.4, 3.2)	0.7 (0.3, 1.5)	0.7 (0.5, 0.9)
Patient sex, F v. M	0.7 (0.4, 1.2)	0.9 (0.5, 1.8)	1.3 (0.8, 2.0)	1.3 (0.7, 2.3)	0.5 (0.2, 1.2)	0.5 (0.3, 0.9)	1.0 (0.8, 1.2)

*Values are odds ratios (with 95% confidence intervals). Screened values are those found to be significant at $p < 0.05$.
†Generalized estimating equations for logistic regression were used. Each variable in the table is adjusted for all others.
OA = osteoarthritis

by some authors to minimize adverse outcomes.[7,10] To the best of our knowledge, no previous study has involved Canadian data. Since the surgeon and hospital provider volume distributions in the United States differ markedly from the Canadian distributions, conclusions derived from the United States may not be applicable to other countries. At present there is no evidence to support regionalization of elective hip replacement operations in Ontario based on adverse clinical outcomes requiring hospital readmission. Indeed, it has been suggested that devolution of hip replacement operations into the community might save health dollars in Ontario.[25]

One of the advantages of using administrative datasets such as that of the CIHI is that an entire population can be captured, essentially limiting loss to follow-up to patients who left the province during the study period. Unfortunately, since most of these datasets were not designed with clinical research in mind, important outcome data are often lacking. Future work must focus on important patient-related outcomes, such as pain, return to function and health status, that must be obtained prospectively according to a specific data collection protocol. If it can be demonstrated that decreased length of overall hospital stay may be achieved without compromising clinical and functional outcomes, this knowledge should be exploited to maximize the use of our hospital resources.

Table IV

Adjusted Comparison of Length of Stay and Hospital Charges by Provider Group

Variable*	Length of hospital stay,† d
Surgeon volume	
< 9 v. > 27	2.4 (1.3, 3.4)
9–27 v. > 27	1.2 (0.7, 1.7)
Hospital volume	
< 42 v. > 107	0.0 (–0.9, 0.7)
42–107 v. > 107	–0.5 (–1.0, –0.0)
Patient age, /10 yr	0.9 (0.9, 1.0)
Patient comorbidity, 1 v. 0	1.3 (0.6, 2.0)
Patient diagnosis, OA v. non-OA	–1.7 (–2.6, –0.8)
Patient sex, F v. M	0.6 (0.2, 1.0)
Discharge disposition, home v. transfer‡	0.7 (0.1, 1.3)

*Generalized estimating equation regression techniques were used. Each variable in the table is adjusted for all others.
†Values are beta coefficients (with 95% confidence intervals). These coefficients may be interpreted as "days" for length of stay. Screened values are those found to be significant at $p < 0.05$.
‡Home = the patient was discharged home with or without home care. Transfer = the patient was discharged to a rehabilitation facility or other institution following hip replacement.
OA = osteoarthritis

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SESAP Critique / Critique SESAP

ITEM 502

The chest x-ray and chest computed tomographic (CT) scan demonstrate an anterior mediastinal mass. The differential diagnosis of anterior mediastinal masses includes thymoma, pericardial cyst, lymphoma, germ cell neoplasm, aneurysm, lipoma, parathyroid tumor, and parasternal hernia. Klinefelter's syndrome (XXY chromosomal karyotype) is associated with the increased risk of both gonadal and extradonadal germ cell neoplasms, often located in the anterior mediastinum. These germ cell neoplasms include benign and malignant teratomas, seminomas, embryonal cell carcinomas, choriocarcinoma, and endodermal sinus tumors. Teratomas consist of mixtures of well-differentiated adult tissue types of ectodermal, mesodermal, and endodermal origins. Teratomas often have a single or multicystic configuration. The radiologic finding of mature bone or a tooth in an anterior mediastinal tumor (as seen in the imaging studies of this patient) strongly supports the diagnosis of teratoma.

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