Associations between provider and hospital volumes and postoperative mortality following total hip arthroplasty in New Brunswick: results from a provincial-level cohort study

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Background: Several international studies have reported negative associations between hospital and/or provider volume and risk of postoperative death following total hip arthroplasty (THA). The only Canadian studies to report on this have been based in Ontario and have found no such association. We describe associations between postoperative deaths following THA and provider caseload volume, also adjusted for hospital volume, in a population-based cohort in New Brunswick.

Methods: Our analyses are based on hospital discharge abstract data linked to vital statistics and to patient registry data. We considered all first known admissions for THA in New Brunswick between Jan. 1, 2007, and Dec. 31, 2013. Provider volume was defined as total THAs performed over the preceding 2 years. We fit logistic regression models to identify odds of dying within 30 and 90 days according to provider caseload volume adjusted for selected personal and contextual characteristics.

Results: About 7095 patients were admitted for THA in New Brunswick over the 7-year study period and 170 died within 30 days. We found no associations with provider volume and postoperative mortality in any of our models. Adjustment for contextual characteristics or hospital volume had no effects on this association.

Conclusion: Our results suggest that patients admitted for hip replacements in New Brunswick can expect to have similar risk of death regardless of whether they are admitted to see a provider with high or low THA volumes and of whether they are admitted to the province's larger or smaller hospitals.

Contexte : Plusieurs études internationales rapportent un lien négatif entre le volume d'activité de l'hôpital ou du fournisseur de soins de santé et le risque de décès postopératoire lié à une arthroplastie totale de la hanche. Les seules études canadiennes qui se sont intéressées à cette question ont été réalisées en Ontario et n'ont pas rapporté ce lien. Dans notre étude, nous tentons de décrire des liens entre le décès postopératoire lié à une arthroplastie totale de la hanche et le volume de la charge de travail du fournisseur de soins de santé, également ajustés pour tenir compte du volume d'activité de l'hôpital, au sein d'une cohorte basée sur la population au Nouveau-Brunswick.

Méthodes : Nos analyses reposent sur les données portant sur les congés des hôpitaux, associées aux statistiques de l'état civil et aux données des registres des patients. Nous avons examiné toutes les premières hospitalisations connues en vue d'une arthroplastie totale de la hanche au Nouveau-Brunswick entre le 1er janvier 2007 et le 31 décembre 2013. Le volume d'activité du fournisseur de soins de santé a été défini comme étant la totalité des arthroplasties totales de la hanche pratiquées au cours des 2 années précédentes. Nous avons ajusté les modèles de régression logistique de manière à identifier le risque de décès dans les 30 et 90 jours en fonction du volume de la charge de travail du fournisseur de soins de santé, pour tenir compte de caractéristiques personnelles et contextuelles choisies.

Résultats : Environ 7095 patients ont été admis pour une arthroplastie totale de la hanche au Nouveau-Brunswick au cours de la période de 7 ans à l'étude, et 170 patients sont décédés dans les 30 jours. Nous n'avons pas observé de liens entre le volume d'activité du fournisseur de soins de santé et la mortalité postopératoire dans nos modèles. L'ajustement pour tenir compte des caractéristiques contextuelles ou du volume d'activité de l'hôpital n'a eu aucune incidence sur ce lien.

Conclusion : Nos résultats suggèrent que les patients hospitalisés afin de subir une arthroplastie de la hanche au Nouveau-Brunswick peuvent s'attendre à un risque similaire de décès, peu importe que leur fournisseur de soins de santé pratique un volume faible ou élevé d'arthroplasties totales de la hanche ou que le patient soit admis dans un petit ou un grand hôpital de la province.

Extensive research has established that for some surgeries, higher provider caseload volume and/or higher hospital volumes are associated with lower risk of postoperative death.[1–3] This association is based on the assumptions that higher-volume hospitals will have structural characteristics associated with better quality of care and that care providers, including staff, nurses and physicians, may offer improved levels of care owing to their increased levels of experience. There is interest in this topic in the context of the centralization of surgical services away from smaller, lower-volume hospitals toward larger, higher-volume facilities to reduce health care costs and improve patient outcomes.

Although there is a rich literature on associations between provider and hospital volumes and surgical outcomes, there is a deficiency of studies pertaining specifically to hip surgeries[4] and of studies that jointly assess the effect of provider volume and hospital volume.[3] Moreover, only a handful of studies have explored this issue in Canada.

Several American studies have reported negative associations between hospital or provider volume and risk of death following total hip arthroplasty (THA).[5–7] Despite selected examples of negative associations, a recent systematic review of 32 studies examining THA and mortality concluded that the effect of provider or hospital volume on mortality following THA remains inconclusive, owing in part to differences in study designs.[8] This same review noted that owing to differences in training, organization of health care and general practices, findings from American studies may not be generalizable to other contexts.[8]

A Canadian study from 1998 of about 3600 patients in Ontario found no association between provider or hospital volumes and either 3-month or 1-year mortality following THA.[9] A larger and more recent Ontario study of 20 290 THA patients also reported no associations between provider volume (n = 261) or hospital volume (n = 62; measured as average annual procedures over a 4-year period) and mortality within 90 days of operation.[10] To our knowledge, no other studies on this topic have been conducted elsewhere in Canada, at least in part because of restrictions on access to patient records and administrative health data for research purposes in other provinces. Here, we sought to describe associations between postoperative deaths following THA and provider caseload volume, also adjusted for hospital volume, in New Brunswick, Canada.

Methods

All analyses were conducted in the New Brunswick Institute for Research, Data, and Training (NB-IRDT), a research institute at the University of New Brunswick that was established in 2015 through collaboration with several provincial government departments. The NB-IRDT provides a central location for researchers to access and link provincial health-related and other data sets, including anonymized patient records, as well as clinical and administrative databases, such as the provincial cancer registry. Our analyses in the present study are based on hospital discharge abstract database (DAD) linked to Vital Statistics (to determine time of death) and to citizen registry data (to determine age and other patient characteristics). The University of New Brunswick Research Ethics Board approved our study protocol.

Cohort identification

We considered all first known admissions for surgeries for THA (ICD intervention code 1.VA.53.XX) between Jan. 1, 2007, and Dec. 31, 2013, from the New Brunswick DAD. These records include admissions from all 8 hospitals in the province that perform hip replacement surgeries. First admission was estimated by reviewing patient records beginning on Jan. 1, 2003 (i.e., 4 years before baseline).

In addition to diagnosis and intervention codes, the DAD includes patient age, sex, comorbidity,[11] urgency of admission and 6-digit postal code of residence. Providers were identified using the physician identifier in the DAD. We included all surgeons who performed at least 1 THA in New Brunswick during the study period.

In the absence of personal-level socioeconomic information on patients, the patients' residential postal codes were geocoded using Statistics Canada's Postal Code Conversion File Plus v.6C. This program uses a population-weighted allocation algorithm to identify representative geographic coordinates for postal codes in Canada so that participants can be assigned to the following contextual characteristics: neighbourhood income quintile and size of home community.[12] The community-specific neighbourhood income quintiles are a household size–adjusted measure of household income based on 2006 census data at the dissemination area level. The community size variable is based on 2011 census population data, and in the context of New Brunswick, includes 3 categories: urban centres with populations between 100 000 and 499 000, small towns with populations between 10 000 and 99 999 and rural areas with populations of fewer than 10 000 people.

Outcomes

Patient DAD records were linked with Vital Statistics data to identify postoperative deaths. The primary outcome used in this analysis was 30-day postoperative death, defined as death from any cause in the period from the day of discharge from hospital to 30 days afterwards.

Volume definitions

In 91% of admission records only 1 provider was listed as having performed an intervention. For the remaining 9%, we identified the provider who performed the most extensive kind of intervention as the responsible provider. We counted

an intervention toward a provider's caseload volume regardless of whether he or she was the sole provider associated with an admission. That is, in some cases, 2 providers were deemed to have gained experience/volume from participating in a surgery, but only 1 was deemed responsible for the outcome. We then defined provider caseload volume as a continuous variable describing annual mean procedure-specific interventions performed in New Brunswick over a 2-year period as a moving window preceding each new intervention (approximated using 730 days before surgery date). Thus, we updated each provider's estimate of past volume for each new procedure performed. This approach allowed us to control for temporal changes in provider volume over the study period. For example, at one point in time, a given provider may have performed only 15 procedures in the previous 2 years, whereas at another point in time, he or she may have performed many more than that.

We also calculated hospital volume as a continuous variable, indicating the number of THAs performed within the 2 years before the date of discharge. For the purposes of testing effect modification, we also dichotomized hospitals into categories of relatively high and low volume as follows: the 4 community–medium hospitals were categorized as low, and the 4 community–large hospitals were categorized as high. This classification was determined following initial scans of the data and knowledge of the sizes and locations of the hospitals in the province.

Statistical analysis

We used logistic regression to identify the odds of dying according to provider caseload volume, adjusted for patient age, sex and comorbidity level. Next, we fit additive models to adjust for contextual covariates, including neighbourhood income quintile and size of home community, and for hospital volume. We then fit similar models for surgeries performed in high- and low-volume hospitals separately.

Additionally, to test the sensitivity of our results, we fit models stratified by hospital and models that excluded providers with fewer than 3 interventions over the entire study period. Finally, we also fit all models with 90-day postoperative death as the outcome.

Results

Our study cohort consisted of about 7095 patients admitted for THA over the 7-year period. Sample sizes reported here have been rounded randomly to the nearest 5 for institutional confidentiality. About 80% of all patients were admitted to 1 of the 4 high-volume hospitals (Table 1). About 40% of patients were men, and mean ages were 68 years for men and 74 years for women. Both high- and low-volume hospitals received approximately equal distributions of elective and urgent cases as well as similar case mixes, according to the comorbidity level. Patients presenting at the higher-volume hospitals were notably from more urban areas of the province; nearly half of those presenting at high-volume hospitals came from a city with a population greater than 100 000 people (i.e., Moncton or Saint John), whereas no patients from these cities presented at the lower-volume hospitals. Additionally, patients presenting at the higher-volume hospitals tended to come from higher-income neighbourhoods; 43.4% of patients from medium- to high-income neighbourhoods presented at the high-volume hospitals, whereas only 33.6% of patients from neighbourhoods in those income quintiles presented at the low-volume hospitals.

On average, 57 and 213 interventions for THA were performed annually at the low- and high-volume hospitals, respectively (Table 2). A handful of providers performed interventions in both the low- and high-volume hospitals at different times over the study period. As such, a few surgeons contributed to the number of providers who operated in both the low- and high-volume hospitals listed in Table 2. In total, 170 patients died during the 7-year study period, with approximately similar crude mortality occurring in both low- and high-volume hospitals. Two-year annual mean caseload volumes of providers in high-volume hospitals were more than double those in low-volume hospitals (53.8 v. 22.2).

Table 1. Characteristics of patients admitted for total hip arthroplasty at low- and high-volume hospitals in New Brunswick (2007–2013)

Characteristic	Low-volume hospitals	High-volume hospitals
No. of admissions	1490	5605
Mean age, yr		
Men	68.58	68.01
Women	75.09	73.57
Male patients, %	40.60	39.43
Admission status, %		
Elective	62.08	63.43
Urgent	37.92	36.57
Comorbidity, %		
None (0)	85.91	84.57
Mild (1–2)	8.05	8.47
Moderate to severe (3–4)	3.02	3.48
Missing/not applicable	3.02	3.48
Community size classification, %		
City*	0.00	43.89
Small town†	54.03	16.95
Rural area‡	45.97	39.16
Neighbourhood income quintile, %		
Lowest	24.50	18.02
Medium-low	22.48	18.29
Middle	19.46	20.25
Medium-high	17.11	22.93
Highest	16.44	20.52

*Population 100 000 to 499 999 people.
†Population 10 000 to 99 999 people.
‡Population < 10 000 people.

We found no associations between provider volume and 30-day postoperative mortality in any of our models (Table 3 and Table 4). Adjusting our base model (Model 1) for patient contextual characteristics (Model 2) and hospital volume (as a continuous variable; Model 3) had essentially no effect on model fit or on any effect estimates (Table 3). As expected, severe comorbidity was the biggest risk factor for death (odds ratio [OR] 15.65, 95% confidence interval [CI] 8.75–28.01) compared with having no comorbid conditions (Model 3; Table 3). Similarly, patients admitted for urgent interventions had significantly higher odds of dying than those admitted for elective interventions (OR 5.82, 95% CI 3.50–9.67). Patients living in rural areas were significantly more likely to die than those living in the largest cities (OR 1.51, 95% CI 1.02–2.22). Older age and male sex were also significant risk factors for death.

Table 2. Characteristics of hospitals with relatively low and high volumes for total hip arthroplasty in New Brunswick (2007–2013)

Characteristic	Low-volume hospitals	High-volume hospitals
No. of hospitals	4	4
No. of providers	19	33
Mean annual hospital volume	57.39	213.45
Mean annual provider caseload	22.21	53.76
30-day mortality, %	2.35	2.50
Elective admissions, %	0.54	0.56
Urgent admissions, %	5.31	5.85

Patients admitted as urgent cases and those with severe comorbidities had somewhat higher odds of dying when admitted to a low-volume hospital than to a high-volume hospital (Table 4). Otherwise, there were no substantial differences in outcomes between the high- and low-volume hospitals.

In our sensitivity analyses, neither stratification by hospital nor exclusion of providers with fewer than 3 interventions performed during the study period had any substantial impacts on the association between provider volume and mortality (results not shown). Similarly, we found no associations with provider volume and 90-day mortality in any of our models (results not shown).

Discussion

In this relatively large, population-based study, covering 7 years of surgeries performed at all hospitals in the province of New Brunswick, we found no association between provider volume in the preceding 2 years and postoperative mortality following THA. Adjustment for contextual characteristics or hospital volume had no effects on this association or on model fit. Hip arthroplasty is one of the most common operations in orthopedic practice, and admissions for this intervention in Canada have been increasing by approximately 5% per year since 2009.[13] It is therefore notable that for this common procedure, our results suggest that provider volume does not appear to influence the risk of postoperative death.

Consistent with previous studies, Canadian or otherwise, patient characteristics rather than volume were the most

Table 3. Odds ratios for selected characteristics and 30-day postoperative mortality following total hip arthroplasty (n = 7095)

	Model, OR (95% CI)		
Characteristic	Model 1, R^2 = 0.21	Model 2, R^2 = 0.22	Model 3, R^2 = 0.22
Provider volume	1.00 (0.99–1.01)	1.00 (0.99–1.01)	1.00 (0.99–1.01)
Patient age, yr	1.05 (1.03–1.06)	1.04 (1.03–1.06)	1.04 (1.03–1.06)
Patient sex (female v. male)	0.60 (0.43–0.85)	0.61 (0.43–0.86)	0.61 (0.43–0.86)
Admission category (urgent v. elective)	5.73 (3.45–9.51)	5.75 (3.46–9.55)	5.82 (3.50–9.67)
Patient comorbidity (level v. none)			
1	3.58 (2.21–5.80)	3.58 (2.21–5.81)	3.59 (2.21–5.83)
2	3.48 (2.11–5.73)	3.43 (2.08–5.67)	3.49 (2.11–5.77)
3	4.71 (2.69–8.26)	5.03 (2.86–8.87)	5.10 (2.89–8.98)
4	13.67 (7.77–24.05)	15.25 (8.56–27.16)	15.65 (8.75–28.01)
Missing/not applicable	2.04 (0.92–4.56)	2.07 (0.93–4.63)	2.05 (0.92–4.59)
Neighbourhood income quintile (v. lowest)			
Medium-low	—	1.12 (0.69–1.82)	1.12 (0.68–1.82)
Middle	—	0.89 (0.52–1.51)	0.89 (0.52–1.51)
Medium-high	—	1.12 (0.70–1.78)	1.12 (0.71–1.79)
Highest	—	0.85 (0.49–1.46)	0.85 (0.50–1.47)
Community size (v. city [population 100 000 to 499 000])			
Small town (population 10 000 to 99 999)	—	1.11 (0.71–1.75)	1.05 (0.66–1.69)
Rural area (population < 10 000)	—	1.56 (1.07–2.27)	1.51 (1.02–2.22)
Hospital mean annual THA volume	—	—	1.00 (1.00–1.00)

CI = confidence interval; OR = odds ratio; THA = total hip arthroplasty.

significant predictors of postoperative complications (in this case death) following THA.[8–10] Our finding of no association between provider volume and postoperative death following THA are consistent with those of the only other Canadian studies we identified.[9,10,14] These findings, however, are inconsistent with some American,[5,7,15] Chinese[16] and UK-based[17] studies that reported improved postoperative mortality following THA was associated with increased provider and hospital volume. Overall, 0.56% of patients admitted for elective surgery, 5.74% admitted for urgent care and 2.47% of all patients died within 30 days; the 90-day mortality was 0.67%, 8.60%, and 3.59%, respectively. These values for elective surgeries are comparable to those reported in Ontario (0.60% within 90 days)[10] and are within the ranges of pooled estimates from a large systematic review[8] that reported pooled rates of 0.30% (95% CI 0.22–0.38) and 0.65% (95% CI 0.50–0.81), respectively. These studies did not report results for urgent admissions.

Strengths and limitations

Key strengths of our study were that we had access to patient-level data linked to vital statistics and that we could link surgical events by provider, both of which are not available in several of other provinces owing to differing legislation guiding the use of health data for research purposes. To our knowledge, this is the first Canadian study outside of Ontario to examine the association between either provider or hospital volume and postoperative death following THA. Our analyses are based on a relatively large cohort of more than 7000 patients and, moreover, include all (and only) first known admissions for THA in the province of New Brunswick over the 7-year study period. Our provincially representative cohort consists of an approximately equal distribution of patients from medium-sized cities, small towns and rural areas. Another strength of this study is that we were able to adjust for provider caseload volume along with hospital volume simultaneously. Most studies of volume–outcome associations have focused exclusively on only one of these. Furthermore, our method of calculating a moving window of procedure volume over the previous 2 years for each provider allowed us to incorporate changes in volumes over the 7 years of follow-up.

It should be acknowledged that even though we included records from all hospitals in the province, there are in fact only 8, which is a relatively small sample size of facilities compared with the samples of studies conducted elsewhere. For this reason, we focused our analyses on associations with provider volume rather than on differences in outcomes between facilities.

A limitation of this study is that we could include data only for interventions performed in New Brunswick by New Brunswick-based providers on New Brunswick residents. We did not have information on providers visiting from out of province (which may or may not happen in some cases), nor did we have any record of providers' experiences conducted elsewhere (e.g., before moving to New Brunswick). Additionally, locum surgeons who are not regularly practising orthopedic surgeons in New Brunswick may have performed some of the surgeries. Given that the earliest DAD records available to us began in 2003 and that

Table 4. Odds ratios for selected characteristics and 30-day postoperative mortality following total hip arthroplasty, by high- and low-volume hospitals

	Hospital volume; OR (95% CI)	
Characteristic	High-volume, R^2 = 0.21, n = 5605	Low-volume, R^2 = 0.26, n = 1490
Provider volume	1.00 (0.99–1.01)	0.99 (0.96–1.03)
Patient age, yr	1.05 (1.03–1.07)	1.04 (1.00–1.08)
Patient sex (female v. male)	0.63 (0.43–0.93)	0.47 (0.21–1.04)
Admission category (urgent v. elective)	5.07 (2.90–8.85)	11.26 (3.09–40.99)
Patient comorbidity (level vs. none)		
1	2.85 (1.59–5.12)	7.18 (2.87–17.93)
2	3.50 (2.02–6.04)	2.84 (0.76–10.59)
3	5.35 (2.89–9.89)	3.52 (0.73–16.99)
4	13.58 (7.34–25.13)	39.69 (6.73–234.24)
Missing/not applicable	1.43 (0.50–4.05)	5.46 (1.41–21.16)
Neighbourhood income quintile (v. lowest)		
Medium-low	1.31 (0.75–2.29)	0.62 (0.22–1.77)
Middle	0.94 (0.51–1.74)	0.74 (0.25–2.20)
Medium-high	1.24 (0.73–2.11)	0.81 (0.28–2.32)
Highest	0.89 (0.48–1.65)	0.96 (0.28–3.26)
Community size (v. city [population 100 000 to 499 000])		
Small town (population 10 000 to 99 999)	1.27 (0.74–2.19)	—
Rural area (population < 10 000)	1.47 (0.98–2.20)	—

CI = confidence interval; OR = odds ratio.

interventions performed outside New Brunswick were unknown, the observable time before each admission was not uniform for all patients. Another common limitation of working with administrative data is that we were unable to consider information on other attributes or characteristics of the patients (e.g., other health conditions, health behaviours, or personal socioeconomic characteristics), providers (e.g., years of training, cumulative career surgical experience), or of the hospitals (e.g., size of nursing or provider staff), which may have provided more insight into provider–outcome associations. Aditionally, we considered associations only with short-term, all-cause postoperative mortality. A limitation of this study, therefore, is that we were unable to make any conclusions about other indicators of quality of care. Given that our cohort consisted exclusively of patients admitted for a first THA, our findings may not be generalizable to revision procedures or to partial hip replacements. Moreover, although we found no association between mortality and provider volume, as measured in terms of volume in the preceding 2 years, we did not examine other indicators of experience, such as cumulative career or total (nonspecific) surgical volume.

Conclusion

Our results suggest that, for the most part, patients admitted for hip replacements in New Brunswick can expect to have similar risk of postoperative death, regardless of whether they are admitted to see a provider with relatively high or low THA volumes and of whether they are admitted to one the province's larger or smaller hospitals. As noted, with the exception of patients admitted for urgent care and/or with severe comorbidities, the risk of postoperative death is relatively consistent between the high- and low-volume hospitals.

Future studies may want to consider associations between volume and other more THA-specific outcomes, such as readmission for venous thromboembolism, for revision, or cause-specific mortality, or outcomes beyond 30 and 90 days of surgery.

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