Outcomes for Simultaneous and Staged Bilateral Total Knee Replacement Surgeries

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Total knee replacement (TKR) is one of the most common and costly surgeries performed in Canada. When patients need to have both knees replaced, they and their doctors decide, based on clinical and patient factors, whether to replace the 2 joints during the same surgery (simultaneous TKR) or during separate surgeries (staged TKR). This report provides a comprehensive comparison of outcomes for these 2 surgical approaches patient and TKR characteristics, outcomes and aggregate system costs using the largest Canadian cohort to date. Such findings have relevance for policy, health systems and patients.

Key findings

Between 2006–2007 and 2013–2014, there were 337,065 primary elective TKRs performed in Canada. In terms of patients, 30,188 people had staged bilateral TKRs (BTKRs) and 7,369 had simultaneous BTKRs (80.4% and 19.6%, respectively).

Compared with patients who received staged BTKRs, patients with simultaneous BTKRs

- Had shorter total acute care stays (median of 6 versus 8 days) but a higher proportion of discharges to inpatient rehabilitation (44.7% versus 8.5%). The total rehabilitation stay, where applicable, was also shorter (median of 11 versus 18 days);
- Were more likely to have a blood transfusion during the inpatient stay (37.2% versus 17.3%);
- Had a low proportion of in-hospital deaths, comparable to that of patients who had unilateral TKRs (0.15% and 0.14%, respectively). Staged BTKR mortality could not be estimated in this study;
- Were less likely to have a knee infection during the combined period of their hospital stay and/or the 90-day post-discharge period, although the risk of knee infection was low for both types of BTKRs (0.5% versus 0.9%);
- Had no difference in the need for a revision surgery within 3 years of the primary surgery (1.5% versus 1.4%); and

- Do not appear to have had immediately evident cost savings, based on readily available system cost data. Simultaneous BTKRs are estimated to have lower acute care in-hospital costs ($13,200 versus $16,700 for staged) and lower acute care physician costs ($4,200 versus $5,800 for staged, primary stage only). However, inpatient rehabilitation costs, where applicable, appear to be higher, with an average increment cost of $3,400 per patient versus $1,200 for staged. Therefore, the weighted average costs of simultaneous and staged procedures are comparable, with total costs of $20,800 and $23,700, respectively.

Introduction

The Canadian Joint Replacement Registry (CJRR), managed by the Canadian Institute for Health Information (CIHI), collects data on hip and knee replacement surgeries from across Canada in collaboration with the Canadian Orthopaedic Association, provincial ministries of health and participating orthopedic surgeons.

Each year, approximately 55,000 elective TKRs are performed in Canada. It is estimated that 80% of those age 65 are affected by osteoarthritis in the knee and that, of these, one-third present with bilateral symptoms.[1] For patients who require BTKRs, one of the initial decisions is whether to have both knees surgically replaced with prosthetic joints at the same time or during separate surgeries. Ultimately, the orthopedic surgeon decides on the course of action after considering the patient's demographic factors, disease progress and severity, and preferences and expectations of recovery.

Reasons for choosing a staged approach include asymmetrical severity in knee pain and patient preference.[2] A simultaneous BTKR entails only a single surgery and anesthetic administration, simultaneous pain relief and functional recovery in both knees, and, in some cases, decreased costs and length of hospital stay.[3–5] Patients with severe bilateral arthritis symptoms tend to undergo either a simultaneous BTKR or a staged BTKR with a short staging period.[5]

Other studies have reported mixed results in terms of the benefits of simultaneous versus staged surgeries. Some studies found that the simultaneous BTKR approach offered patients more gains in quality-adjusted life years,[6] were less costly[7] and offered better clinical outcomes.[6, 7] Others found that outcomes of simultaneous BTKRs were worse than those of staged BTKRs[7–11] or unilateral TKRs.[1, 4, 10–13] Yet other investigators found no differences between these surgical approaches.[1–3, 5, 7, 11–13] To date, no published study involving pan-Canadian administrative data has compared these 2 types of BTKR surgeries. This study used the Hospital Morbidity Database (HMDB), a comprehensive pan-Canadian data holding that is used for CJRR reporting, as the primary data source to investigate and compare the patient and BTKR characteristics, outcomes and aggregate system costs for these 2 approaches.

Study cohort and methods

The study cohort was created from all patients in the HMDB who underwent primary elective TKR surgery and were discharged between 2006–2007 and 2013–2014. An additional year of follow-up data from 2014–2015 was used to identify post-discharge outcomes for TKR patients, such as early revisions and readmissions. The cohort was divided into 3 subgroups:

1. Simultaneous BTKRs if both knees were replaced on the same day;
2. Staged BTKRs if both knees were replaced in 2 separate surgeries within 1 year; and
3. Unilateral TKRs if only 1 knee was replaced within 1 year.

Results for the unilateral group are shown for reference only; we did not undertake statistical comparisons with this group. Patient data was linked across inpatient hospitalizations using encrypted health card number. To be included in the study cohort, both stages of the staged BTKR had to occur within the study time frame.

Risks of adverse outcomes for simultaneous surgeries were compared with the cumulative risk over both stages of bilateral staged surgeries (except where otherwise noted). Analyses were adjusted for patient age at time of surgery, sex, presence of comorbidity and facility TKR volume. See the appendix for a more detailed description of the study's methodology.

To carry out the aggregate system costing analysis, acute in-hospital cost estimates were derived from the HMDB using the Cost of a Standard Hospital Stay indicator and the Case Mix Group+ 2014 Resource Intensity Weights.[14, 15] Cost estimates for inpatient rehabilitation were derived from the National Rehabilitation Reporting System using the Ontario-based case-costing methodology developed by the Health System Performance Research Network.[16] The cost estimates for physicians were derived from the Patient-Level Physician Billing Repository, based on Alberta estimates.[17]

Results

Over the 8-year study period, 337,065 primary elective TKRs were performed in Canada. Of these, 7,369 patients underwent simultaneous BTKRs and 30,188 underwent staged BTKRs (with 95% of them staged at least 3 months to a maximum of 1 year apart). Looking at volumes over time (data not shown), simultaneous BTKRs saw little change (-2%); however, staged BTKR volumes increased by 29% over the study period.

Characteristics of TKR patients

As seen in Table 1, simultaneous BTKR patients tended to be younger, male and less likely to have pre-existing comorbidities than staged BTKR patients. About half (49%) of simultaneous patients were age 65 and older, compared with 57% of staged BTKR patients (age recorded at stage 1; data not shown).

Table 1 Characteristics of primary elective total knee replacement patients

Patient characteristic	Unilateral TKR*	Simultaneous BTKR*	Staged BTKR,* first stage	Staged BTKR,* second stage	p-Value† (simultaneous versus staged)
Number of patients (N)	240,152	7,369	30,188	30,188	—
Number of TKRs	269,320	7,369	60,376	60,376	—
Median age (interquartile range)	68 (61–75)	64 (58–71)	66 (60–73)	67 (60–74)	<0.0001
Sex (% male)	39	41	39	39	0.0009
Presence of comorbidity (%)‡	5.1	2.9	4.3	4.4	<0.0001

Notes

* Unilateral TKR: 1 knee replaced within a 1-year period; Simultaneous BTKR: Both knees replaced during the same surgery; Staged BTKR: Both knees replaced in separate surgeries within a 1-year period.

† Comparison between BTKR groups (simultaneous versus first stage of staged BTKR). Significance level set at 0.05.

‡ The Charlson Comorbidity Index methodology was used to define comorbidities for each surgery. Patients were grouped as those who presented with at least 1 predefined comorbid condition (Charlson Comorbidity Index >0) versus none (Charlson Comorbidity Index = 0) for each replacement. Comorbidities include congestive heart failure, dementia, chronic pulmonary disease, rheumatological diseases, mild liver disease, diabetes with organ failure, hemiplegia/paraplegia, renal disease, moderate or severe liver disease, HIV infection and primary or metastatic cancer.

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TKR: Total knee replacement.

Source

Hospital Morbidity Database, 2006–2007 to 2013–2014, Canadian Institute for Health Information.

Simultaneous BTKRs happened more often in facilities with the highest volumes of TKRs, when analyzed by volume quartile (p<0.0001; data not shown). 70% of simultaneous BTKRs took place in the highest-TKR-volume facilities, compared with 55% of the staged BTKRs. Only a small proportion of simultaneous surgeries were performed in facilities with low TKR volumes (9% versus 19% for staged).

Bilateral TKR outcomes

Hospital stay and discharge disposition

As shown in Table 2, simultaneous BTKR patients had a shorter median length of stay in acute care than staged BTKR patients (6 versus 8 days, respectively).

A higher proportion of simultaneous BTKR patients had a blood transfusion during the inpatient stay compared with staged BTKR patients (37% versus 17%). This finding remained significant after adjusting for differences in facility transfusion practice patterns as opposed to the facility TKR volume (data not shown).

A very small proportion of patients who underwent BTKRs died in hospital during the acute care stay (11 simultaneous patients and 16 staged patients, representing 0.15% and 0.05%, respectively). However, these results cannot be statistically compared because the cumulative risk of mortality over both stages of a planned 2-stage procedure could not be estimated (refer to the section Limitations for more information). These are crude mortality rates and do not account for patient or surgery factors.

After the acute care stay, simultaneous BTKR patients were less likely to be discharged directly home (50.1% versus 88.4% for staged). Simultaneous BTKR patients were also more likely to be discharged to inpatient rehabilitation (44.7% versus 8.5% for staged). The remaining patients in each group were transferred to long-term care or another acute care facility.

When they were transferred to inpatient rehabilitation care, simultaneous BTKR patients had a shorter length of stay than staged BTKR patients (median of 11 versus 18 days combined for both stages; data not shown).

Readmissions and revisions

As shown in Table 2, the risk of readmission with a knee infection within 90 days of discharge was lower for simultaneous procedures (0.4% versus 0.9% combined risk for both stages). The risk was higher for the second stage of the staged BTKR (0.6% versus 0.3% for the first stage; data not shown). The median acute care length of stay for patients returning to hospital because of the infected knee was 7 days. Similar results were found when calculating the knee infection risk over the combined period of the inpatient stay and 90 days post-discharge — the risk was lower for the simultaneous BTKR group by 50%.

However, when comparing the rates of the other 2 common adverse TKR outcomes — cardiac complications (acute ischemia, infarction and arrhythmia) and pulmonary embolism — no difference was found between the 2 BTKR approaches over the combined period of the inpatient stay and 90 days post-discharge.

Simultaneous and staged BTKR patients had similar rates of revision within 3 years of primary surgery (1.5% and 1.4% at 3 years, respectively).

Table 2 Outcomes of simultaneous versus staged bilateral total knee replacements

Outcome*	Unilateral TKR†	Simultaneous BTKR†	Staged BTKR†,‡	p-Value§
Hospital stay and discharge disposition				
Median total inpatient length of stay (days)**	4	6	8	<0.0001
Blood transfusion (%)	12.2	37.2	17.3	<0.0001
In-hospital mortality (due to any reason) (%)††	0.14	0.15	0.05††	—††
Discharge disposition to level of care (%)‡‡				<0.0001‡‡
Transfer to acute care	2.4	2.9	2.0	—
Transfer to general/special rehab	9.1	44.7	8.5	—
Transfer to chronic care/nursing home/home for the aged	1.1	2.1	0.9	—
Transfer to other/unclassified care	0.1	0.2	0.1	—
Home or a home setting with support services from external agency§§	33.1	21.5	32.5	—
Home with no support services from external agency§§	54.2	28.6	55.9	—
Readmissions and revisions				
Knee infection complication rate (90-day readmission) (%)***	0.6	0.4	0.9	0.0022
Overall complication rate (inpatient and/or 90-day readmission)††† (%)***				
Cardiac complications	1.4	1.9	1.8	0.14
Pulmonary embolism	0.8	1.1	1.0	0.56
Knee infection	0.7	0.5	0.9	0.0045

Outcome*	Unilateral TKR†	Simultaneous BTKR†	Staged BTKR†, ‡	p-Value§
Revision rate (% of TKRs)				
1 year	1.1	0.7	0.7	0.76
2 years	1.9	1.1	1.1	0.97
3 years	2.4	1.5	1.4	0.59

Notes

* Outcomes represent percentage of patients affected, except where otherwise noted.

† Unilateral TKR: 1 knee replaced within a 1-year period — 29,168 patients had 2 surgeries, each on a different side; Simultaneous BTKR: Both knees replaced during the same surgery; Staged BTKR: Both knees replaced in separate surgeries within a 1-year period.

‡ Outcomes were calculated over both stages and were counted if present at least once, except where otherwise noted.

§ Comparison between BTKR groups (simultaneous versus combined stages, unless otherwise noted). p-Value after adjusting for patient age at time of surgery, sex, presence of Charlson comorbidity and facility TKR volume. Significance level set at 0.05.

** Total length of stay for staged BTKR was first calculated for each patient and then combined over the 2 stages; there was a median of 4 days per hospital stay at each stage.

†† Based on second stage only. No statistical comparisons were undertaken because patients who died during the first stage of the staged procedure cannot be distinguished from the unilateral patients.

‡‡ For staged BTKRs, overall discharges after either stage of the staged BTKR (per number of knees replaced). p-Value represents comparison with the second surgery discharge. Includes only patients discharged alive. Each jurisdiction's definition for the level of care can vary. Excludes patients who left against medical advice and were absent without leave.

§§ Support services are related to activities of daily living and not to rehabilitation care.

*** Patients discharged before 2009–2010 were excluded due to coding differences (diagnosis cluster was not available).

††† If a patient experienced a complication (cardiac, pulmonary embolism or infection) in hospital and/or was readmitted with it within 90 days, 1 combined event was coded.

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BTKR: Bilateral total knee replacement.

Source

Hospital Morbidity Database, 2006–2007 to 2014–2015, Canadian Institute for Health Information.

System costs

We undertook an aggregate system cost analysis using readily available estimates, spanning the inpatient acute and inpatient rehabilitation episodes of care. Acute in-hospital costs, excluding physician costs, were calculated to be an average of $13,200 for each simultaneous BTKR surgery in the study cohort, lower than the average of $16,700 for each staged surgery (stages combined). Fee-for-service physician costs covering surgeon, anesthesiologist and other physician services during the acute inpatient stay were estimated to be an average of $4,200 for each simultaneous surgery, again lower than the average of $5,800 for staged BTKRs (stages combined). For patients requiring inpatient rehabilitation services, costs for simultaneous surgeries were estimated at $7,600 (plus or minus $3,000), and costs for staged BTKRs were estimated at $7,000 (plus or minus $3,900) for the first stage and $7,600 (plus or minus $4,200) for the second stage. Considering that 44.7% of simultaneous

patients, 9.4% of first-stage patients and 7.7% of second-stage patients received inpatient rehabilitation (data not shown), the average weighted costs of simultaneous and staged surgeries were similar, with total costs of $20,800 and $23,700, respectively, for inpatient acute care, physician services and inpatient rehabilitation.

Discussion

Hospital stay and discharge disposition

As with any surgery, the risk of blood loss and subsequent need for blood transfusion is inherent to TKRs. Blood loss is reported to range from 1,450 mL to 1,790 mL, leading to anemia in many patients.[18] This study found that the rate of blood transfusion in the simultaneous group was twice that of the staged group (37.2% versus 17.3%; $p<0.0001$). Simultaneous BTKRs involve bilateral bone cuts with exposed cancellous bone, as well as increased general trauma to the tissue, which may increase blood loss. Fu et al. hypothesized that with a long enough time between staged procedures, hemopoiesis would adequately replenish blood supply after the first surgery.[7] Data on volume of blood transfused was not available for this study; however, other authors have noted that patients who underwent simultaneous surgeries were not only more likely to receive a blood transfusion, but also required a higher volume of blood.[2, 12, 13] These results should be interpreted with caution, since blood transfusion practices and their reporting may vary across facilities and surgeons.[3, 7] Topical application of tranexamic acid (TXA), a novel approach for reducing blood loss after TKR,[18] may potentially reduce the significant gap between the 2 types of BTKRs. The use of TXA is associated with significant reduction in transfusion rates regardless of type of BTKR.[19]

The in-hospital mortality rate for simultaneous BTKRs (0.15%) is consistent with that reported in the most recent large-scale American study involving more than 400,000 TKRs[20] (0.15%), which compared simultaneous BTKRs with unilateral procedures. Although the risk of mortality was low for all 3 types of TKRs, the mortality in the staged group could not be estimated based on the second surgery's mortality rate alone (this would underestimate the risk of mortality over both stages), while mortality may be overestimated in the unilateral group (deaths during the first stage of the planned 2-stage procedure cannot be distinguished from deaths after unilateral surgery). Mortality risk estimates should be interpreted carefully for studies not capturing intended course of treatment. A recent study showed that about one-third of patients abort the planned second surgery, with a higher refusal rate among patients older than 70.[21] In our cohort, the median age for stage 1 of the staged BTKR was 66. Patients receiving simultaneous TKRs were typically younger.

Readmissions and revisions

Given the typically short length of stay for TKRs, perioperative complications may not present before discharge. Symptoms of deep wound infections in particular may take longer to become apparent. This study found that the rate of knee infection immediately after surgery was negligible compared with the rate of infections that occurred within 90 days post-discharge. In that 90-day post-discharge period, the knee infection rate was significantly higher for staged BTKRs (0.9%) than for simultaneous (0.4%). When comparing the 2 bilateral groups over both episodes (in hospital and 90 days post-discharge combined), those who underwent staged procedures were more likely to develop an infection than those who underwent simultaneous BTKRs. Several studies have found that the risk of developing a deep joint or wound infection (but not a superficial infection) is lower among simultaneous BTKR patients than staged BTKR patients.[7, 22, 23]

Evidence for an increased rate of cardiac complications associated with simultaneous BTKRs has been unclear, with differing conclusions among studies, including 2 large meta-analyses.[1, 3, 12, 13] The current study found that patients who underwent simultaneous BTKRs had a similar rate of cardiac complications to those who underwent staged surgeries, looking at the combined risk of a cardiac complication occurring during the inpatient and 90-day post-discharge periods (1.9% versus 1.8% for staged). It is important to consider the role of cardiovascular comorbidities in the choice of surgical intervention, as simultaneous BTKRs may be avoided in patients with existing cardiovascular diseases.[2]

Some studies have reported that increased surgical time, coupled with simultaneous bilateral intervention and a prolonged period of immobility, may explain the increased risk of pulmonary or cerebral fat embolism after simultaneous BTKRs;[3, 8, 10] however, this study found that patients who underwent simultaneous BTKRs were not at a higher risk of suffering from pulmonary embolism than those who had staged surgeries (1.1% versus 1.0%). This study's findings are similar to those of others that reported no increased risk of pulmonary embolism for simultaneous BTKRs.[12, 13]

This study found that patients who underwent simultaneous surgeries had similar revision rates (up to 3 years post-surgery) as those who underwent staged surgeries. A large meta-analysis by Fu et al. found that simultaneous procedures were associated with lower revision rates than staged procedures.[7, 23] Differences between American and Canadian patients undergoing each procedure could influence these findings. American TKR patients tend to be younger, the U.S. TKR rate is 1.5 times the Canadian rate and the U.S. revision rate is twice as high.[24] In both Ritter's and Meehan's studies comparing simultaneous and staged BTKRs, the proportion of knee replacement patients undergoing BTKR (as opposed to unilateral TKR) was much larger than in this current study's Canadian cohort.[22, 23]

Costs

Approximately 55,000 elective TKRs are performed in Canada every year, with an estimated acute care cost of nearly $400 million, excluding physician costs. The cost of the related rehabilitation services cannot be overlooked. In Ontario alone, prior to 2012, $124 million was spent annually on primary unilateral TKRs (direct costs), and more than $42 million was spent annually for the related rehabilitation, with significant cost variation.[25]

While the hospital and physician costs for staged BTKRs are higher than those for simultaneous surgeries, the total cost of post-surgery rehabilitation may be higher for simultaneous BTKRs. Upon discharge, nearly half (44.7%) of patients in the simultaneous group were transferred to inpatient rehabilitation, compared with 8.5% in the staged group. Other studies have confirmed these findings, reporting that more than one-third of simultaneous bilateral surgery patients were discharged to inpatient rehabilitation.[12, 13, 26]

There are also cost implications for blood transfusions; Canadian Blood Services' cost per unit for 2012–2013 was $386.[27] These costs may be avoided in the future with the introduction of novel approaches, such as TXA, to reduce blood loss.

Other health care costs, including outpatient rehabilitation, outpatient clinic visits and home care, could also widen or narrow the gap. Therefore, health care cost savings from performing BTKRs simultaneously are not clearly evident, considering the longer and more expensive post-operative rehabilitation required and also the variation in practices across jurisdictions.

Limitations

Several limitations should be noted when interpreting the results of this study. The study cohort includes only actual surgeries that took place, which may not reflect the originally intended course of treatment. This may suggest selection bias, making staged BTKR outcomes appear to be more positive than they would be otherwise. The unilateral TKR group includes single TKRs and also cases where

- The second stage of a BTKR surgery was abandoned because of complications, poor results, death or other factors; and
- The first and second procedures of a staged BTKR occurred more than 1 year apart.

This study also found that patients in the staged BTKR group were significantly older than those in the simultaneous BTKR group, which is consistent with other published studies.[6, 9] Surgeons may be more willing to perform simultaneous procedures on younger, presumably healthier patients. While analysis can be adjusted for age, it is important to consider the possibility that selecting healthier patients for simultaneous procedures may induce selection

bias that cannot be fully adjusted for using the comorbidities captured in the discharge record, making simultaneous BTKR outcomes appear more positive than they would otherwise and narrowing the difference between staged and simultaneous outcomes.

This study did not do a statistical comparison between the in-hospital mortality rates of simultaneous BTKR patients and those of either the staged bilateral or unilateral TKR group, as patients who died during the first stage of the staged procedure cannot be distinguished from the unilateral patients. Caution should be exercised while interpreting in-hospital mortality estimates for unilateral and staged procedures.

The system cost analysis used readily available costing estimates, which were derived from different provinces and years. Fee-for-service physician costs were based on Alberta estimates; these costs may not be comparable with those of other provinces, for instance, due to provincial differences in remuneration practices (such as the use of complexity scores for reimbursement purposes).[28] Estimates presented for inpatient rehabilitation, average length of stay and cost should be interpreted with caution, as large variation exists among jurisdictions with regard to where patients receive post-operative rehabilitation.[29] The estimates of inpatient rehabilitation cost are based on data from Ontario only, using the inpatient rehabilitation Cost per Weighted Case indicator, which was available for 45 hospitals as of 2010–2011. There are additional costs to be considered, such as lost work time, the need for caregiver support and outpatient drug costs.

This study did not evaluate the potential impact of different types of facilities that carry out simultaneous BTKRs, besides accounting for volumes, as it is possible that only certain facilities can accommodate simultaneous BTKRs.[30]

There are other outcomes that we were not able to measure for this report, such as patient-reported outcome measures, home care issues and patient experience.[31]

Conclusion

The outcomes of staged and simultaneous BTKRs have been studied previously. However, mixed findings and a focus on international populations left Canadian clinicians and policy-makers in need of insight specific to Canadian health systems and populations. By analyzing data from a cohort of 37,557 BTKR patients along with 240,152 unilateral TKR patients, this study provides pan-Canadian findings that are relevant to policy, health systems and patients.

By using the largest Canadian cohort of its kind, this study makes an important contribution to the body of knowledge comparing types of TKRs and their outcomes, with a focus on comparing simultaneous versus staged BTKRs. Improved data for monitoring TKRs and revisions is a key role of national registries related to joint replacements, such as CJRR.

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Appendix: Methods

Study cohort and variables of interest

The HMDB is a national data holding managed by CIHI that captures administrative, clinical and demographic information on inpatient separations from all acute care hospitals. Primary TKR records were identified in the HMDB using the Canadian Classification of Health Interventions (CCI) codes 1.VG53.LA.PN.^ and 1.VG53.LA.PP.^ with a status attribute of *primary* and an extent attribute of *bicompartmental* or *tricompartmental*.

The characteristics and outcomes investigated included length of stay in the acute care facility, occurrence of blood transfusion during the surgery, in-hospital mortality, discharge disposition, inpatient complications, 90-day readmission with complications, inpatient and 90-day readmission with complications combined and revision rate. Complications were considered if they presented during the same hospitalization as the knee replacement surgery or within 90 days after the primary TKR. Complications analyzed included cardiac complications (acute ischemia, infarction and arrhythmia), pulmonary embolism and infection (see Table A1).

The rate of early revisions — a subsequent TKR surgery within 3 years of the first surgery — was calculated for each group. It should be noted that 3-year follow-up data was not yet available for all patients in this study cohort (i.e., if the revision was done outside of the data years included in this analysis). Only patients who had sufficient follow-up data (i.e., 3 years) were included. Revision procedures were identified using CCI codes 1.VG.53 and 1.VP.53 and the status attribute of *revision*.

Explanatory variables of interest included patient factors: age, sex and presence of Charlson-based comorbidity (calculated based on coding algorithms provided in Table A2). Volume quartiles were created for the facilities where the TKRs were performed, with the fourth quartile including facilities with the highest volume of TKRs performed per year. All the analyses were adjusted for patient factors and facility TKR volumes to account for possible association between TKR hospital volume and surgical outcomes, as some studies have shown for hip and knee replacement surgeries.[32]

Statistical analysis

The chi-square test was used to compare the distribution of categorical variables between the 2 BTKR groups, while the t-test was used to compare continuous variables by group. Reported p-values for outcomes include adjustment for age, sex, baseline comorbidities and facility TKR volume group, using linear regression for continuous outcomes, logistic regression for binary outcomes and multinomial logistic regression for categorical outcomes. All data and statistical analyses were performed using Statistical Analysis Software (SAS) v9.2 (North Carolina, U.S.). The level of significance was set at 0.05 for all statistical tests.

Table A1 ICD-10-CA codes for complications

Description	ICD-10-CA codes
Cardiac complications: Acute ischemia	I20.0, I20.1, I20.80, I20.88, I20.9, I23.0, I23.1, I23.2, I23.3, I23.4, I23.5, I23.6, I23.80, I23.81, I23.82, I23.88, I24.0, I24.8, I24.9
Cardiac complications: Infarction	I21.–, I22.–
Cardiac complications: Arrhythmia (pre–version 2012)	I47.0, I47.1, I47.2, I47.9, I48.0, I48.1, I49.00, I49.01, I49.1, I49.2, I49.3, I49.4, I49.5, I49.8, I49.9, R00.0, R00.1, R00.2, R00.8
Cardiac complications: Arrhythmia (version 2012 onward)	As of version 2012, category I48 was further expanded as follows: I48.00, I48.01, I48.02, I48.3, I48.4, I48.90, I48.91 (codes I48.0 and I48.1 were no longer valid)
Pulmonary embolism	I26.9, T81.7
Infection	T84.54

Note
ICD-10-CA: International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada.

Table A2 Charlson Comorbidity Index

Description	ICD-10-CA codes	Weight
Myocardial infarction	I21, I22, I25.2	0
Congestive heart failure	I09.9, I25.5, I42.0, I42.5, I42.6, I42.7, I42.8, I42.9, I43*, I50, P29.0	2
Peripheral vascular disease	I70, I71, I73.1, I73.8, I73.9, I77.1, I79.0*, I79.2*, K55.1, K55.8, K55.9, Z95.8, Z95.9	0
Cerebrovascular disease	G45, G46*, H340, I60–I67, I68*, I69	0
Dementia	F00*, F01, F02, F03, F05.1, G30, G31.1	2
Chronic pulmonary disease	I27.8, I27.9, J40, J41, J42, J43, J44, J45, J46, J47, J60, J61, J62, J63, J64, J65, J66, J67, J68.4, J70.1, J70.3	1
Rheumatological diseases	M05, M06, M315, M32, M33, M34, M35.1, M35.3, M36.0*	1
Peptic ulcer disease	K25, K26, K27, K28	0
Mild liver disease	B18, K70.0, K70.1, K70.2, K70.3, K70.9, K71.3, K71.4, K71.5, K71.7, K73, K74, K76.0, K76.2, K76.3, K76.4, K76.8, K76.9, Z94.4	2
Diabetes without organ failure	E10.0, E10.1, E10.6, E10.9, E11.0, E11.1, E11.6, E11.9, E13.0, E13.1, E13.6, E13.9, E14.0, E14.1, E14.6, E14.9	0
Diabetes with organ failure	E10.2, E10.3, E10.4, E10.5, E10.7, E11.2, E11.3, E11.4, E11.5, E11.7, E13.2, E13.3, E13.4, E13.5, E13.7, E14.2, E14.3, E14.4, E14.5, E14.7	1
Hemiplegia or paraplegia	G04.1, G11.4, G80.1, G80.2, G81, G82, G83.0, G83.1, G83.2, G83.3, G83.4, G83.9	2
Renal disease	N03.2, N03.3, N03.4, N03.5, N03.6, N03.7, N05.2, N05.3, N05.4, N05.5, N05.6, N05.7, N18, N19, N25.0, Z49.0, Z49.1, Z49.2, Z94.0, Z99.2	1
Moderate or severe liver disease	I85.0, I85.9, I86.4, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7	4
HIV infection	B24, O98.7	4
Primary cancer	C0, C1, C20, C21, C22, C23, C24, C25, C26, C30, C31, C32, C33, C34, C37, C38, C39, C40, C41, C43, C45, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C57, C58, C6, C70, C71, C72, C73, C74, C75, C76, C81, C82, C83, C84, C85, C88, C90, C91, C92, C93, C94, C95, C96, C97	2
Metastatic cancer	C77, C78, C79, C80	6

Notes

ICD-10-CA: International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada.

For provinces other than Quebec, diagnosis types (1), (W), (X) and (Y) are used to calculate the Charlson Index score, with the following exceptions:

- Diagnosis type (3) is also used for all diabetes codes; and
- Only diagnosis type (3) is used for asterisk (*) codes.

For Quebec, only diagnosis types (1), (C), (W), (X) and (Y) are used to calculate the Charlson Index score.

References

1. Luscombe J, Theivendran K, Abudu A. The relative safety of one-stage bilateral total knee arthroplasty. *International Orthopaedics*. 2009.

2. Yoon H-S, Han C-D, Yang I-H. Comparison of simultaneous bilateral and staged bilateral total knee arthroplasty in terms of perioperative complications. *The Journal of Arthroplasty*. 2010.

3. Patil N, Wakankar H. Morbidity and mortality of simultaneous bilateral total knee arthroplasty. *Orthopedics*. 2008.

4. Memtsoudis S, Ma Y, González Della Valle A, et al. Perioperative outcomes after unilateral and bilateral total knee arthroplasty. *Anesthesiology*. 2009.

5. Forster M, Bauze A, Bailie A, Falworth M, Oakeshott R. A retrospective comparative study of bilateral total knee replacement staged at a one-week interval. *The Journal of Bone and Joint Surgery (British Volume)*. 2014.

6. Odum S, Troyer J, Kelly M, Dedini R, Bozic K. A cost-utility analysis comparing the cost-effectiveness of simultaneous and staged bilateral total knee arthroplasty. *The Journal of Bone and Joint Surgery (American Volume)*. 2013.

7. Fu D, Li G, Chen K, Zeng H, Zhang X, Cai Z. Comparison of clinical outcome between simultaneous-bilateral and staged-bilateral total knee arthroplasty: a systematic review of retrospective studies. *The Journal of Arthroplasty*. 2013.

8. Lee S, Yoon J, Nam C, Kim T, Jung K, Lee D. Cerebral fat embolism syndrome after simultaneous bilateral total knee arthroplasty: a case series. *The Journal of Arthroplasty*. 2012.

9. Stefánsdóttir A, Lidgren L, Robertsson O. Higher early mortality with simultaneous rather than staged bilateral TKAs: results from the Swedish Knee Arthroplasty Register. *Clinical Orthopaedics and Related Research*. 2008.

10. Barrett J, Baron J, Losina E, Wright J, Mahomed N, Katz J. Bilateral total knee replacement: staging and pulmonary embolism. *The Journal of Bone and Joint Surgery (American Volume)*. 2006.

11. Restrepo C, Parvizi J, Dietrich T, Einhorn T. Safety of simultaneous bilateral total knee arthroplasty: a meta-analysis. *The Journal of Bone and Joint Surgery (American Volume)*. 2007.

12. Bullock D, Sporer S, Shirreffs T. Comparison of simultaneous bilateral with unilateral total knee arthroplasty in terms of perioperative complications. *The Journal of Bone and Joint Surgery (American Volume)*. 2003.

13. Lombardi A, Mallory T, Fada R, et al. Simultaneous bilateral total knee arthroplasties: who decides?. *Clinical Orthopaedics and Related Research*. 2001.

14. Canadian Institute for Health Information. *Case Mix Decision-Support Guide: CMG+*. 2009.

15. Canadian Institute for Health Information. *DAD Resource Intensity Weights and Expected Length of Stay for CMG+ 2014*. 2015.

16. Wodchis WP, Bushmeneva K, Nikitovic M, McKillop I. *Guidelines on Person-Level Costing Using Administrative Databases in Ontario*. 2013.

17. Canadian Institute for Health Information. Alberta Patient-Level Physician Billing Data Pilot Project [unpublished internal document]. 2014.

18. Antapur P, Mahomed N, Gandhi R. Fractures in the elderly: when is hip replacement a necessity?. *Clinical Interventions in Aging*. 2011.

19. Zywiel M, Jan Z, Perruccio A, et al. Topical Tranexamic Acid in TKA Lowers Transfusion Rates and Hospital Costs Without Raising Thromboembolic Events. *American Academy of Orthopaedic Surgeons 2015 Annual Meeting*. March 24 to 28, 2015.

20. Odum SM, Springer BD. In-hospital complication rates and associated factors after simultaneous bilateral versus unilateral total knee arthroplasty. *The Journal of Bone and Joint Surgery (American Volume)*. 2014.

21. Sesen H, Demirkale I, Karaduman M, Vural CA, Okkaoglu MC, Altay M. Why two-thirds of patients accepted the second session in staged bilateral total knee arthroplasty: a prospective analysis of 111 patients. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2014.

22. Ritter M, Mamlin L, Melfi C, Katz B, Freund D, Arthur D. Outcome implications for the timing of bilateral total knee arthroplasties. *Clinical Orthopaedics and Related Research*. 1997.

23. Meehan J, Danielsen B, Tancredi D, Kim S, Jamali A, White R. A population-based comparison of the incidence of adverse outcomes after simultaneous-bilateral and staged-bilateral total knee arthroplasty. *The Journal of Bone and Joint Surgery (American Volume)*. 2011.

24. Kurtz S, Ong K, et al. International survey of primary and revision total knee replacement. *International Orthopaedics*. 2011.

25. Ontario Ministry of Health and Long-Term Care. *Quality-Based Procedures Clinical Handbook for Primary Unilateral Knee Replacement*. 2015.

26. Cushner F, Scott W, Scuderi G, Hill K, Insall J. Blood loss and transfusion rates in bilateral total knee arthroplasty. *The Journal of Knee Surgery*. 2005.

27. Canadian Blood Services. *Aligning Our Goals: A Report to Canadians 2012/2013 Summary Report*. 2013.

28. Health Canada. *Arthritis in Canada: An Ongoing Challenge*. 2003.

29. Mahomed NN, Davis AM, Hawker G, et al. Inpatient compared with home-based rehabilitation following primary unilateral total hip or knee replacement: a randomized controlled trial. *The Journal of Bone and Joint Surgery (American Volume)*. 2008.

30. Soohoo N, Lieberman J, et al. Factors predicting complication rates following total knee replacement. *The Journal of Bone and Joint Surgery (American Volume)*. 2006.

31. Baker BN, Petheram T, et al. Comparison of patient-reported outcome measures following total and unicondylar knee replacement. *The Journal of Bone and Joint Surgery (British Volume)*. 2012.

32. Singh JA, Kwoh CK, Boudreau RM, Lee GC, Ibrahim SA. Hospital volume and surgical outcomes after elective hip/knee arthroplasty: a risk-adjusted analysis of a large regional database. *Arthritis and Rheumatism*. 2011.

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