Early Revisions of Hip and Knee Replacements in Canada

A Quality, Productivity and Capacity Issue

Canadian Institute for Health Information
Institut canadien d'information sur la santé

Production of this document is made possible by financial contributions from Health Canada and provincial and territorial governments. The views expressed herein do not necessarily represent the views of Health Canada or any provincial or territorial government.

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ISBN 978-1-77109-914-1 (PDF)

How to cite this document:
Canadian Institute for Health Information. *Early Revisions of Hip and Knee Replacements in Canada: A Quality, Productivity and Capacity Issue*. Ottawa, ON: CIHI; 2020.

Cette publication est aussi disponible en français sous le titre *Reprises précoces des arthroplasties de la hanche et du genou au Canada : un enjeu touchant la qualité, la productivité et les capacités*.
ISBN 978-1-77109-915-8 (PDF)

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Acknowledgements

The Canadian Institute for Health Information (CIHI) wishes to acknowledge the following individuals for their contribution to the development of this report: Carolyn Sandoval, Catherine Yu, Alina Dragan, Saman Brar, Julia Di Bella, Nicole de Guia and Greg Webster. Members of the Financial Standards Information and Physician Information teams are also thanked for their contributions and reviews.

CIHI also wishes to thank the Canadian Joint Replacement Registry (CJRR) Advisory Committee chairs, Dr. Eric Bohm (Concordia Joint Replacement Group, Manitoba) and Dr. Michael Dunbar (Queen Elizabeth II Health Sciences Centre, Nova Scotia), for their leadership and support in the development of this report. A note of appreciation also goes to Dr. Paul Kim (The Ottawa Hospital, Ontario), Dr. Emil Schemitsch (London Health Sciences Centre, Ontario) and Dr. Jason Werle (Alberta Hip and Knee Clinic) for providing clinical advice on specific analyses for this report. We also thank the Advisory Committee members for their advice and support for this work.

Introduction

Over 130,000 hip and knee replacement surgeries are performed in Canada every year. These procedures are 2 of the 3 most common inpatient surgeries in Canada, and the related implants are among the highest-volume and highest-cost medical devices used in Canadian hospitals.[1, 2] With osteoarthritis (OA) being the most common diagnosis for hip and knee replacement patients,[1] demand for these high-volume surgeries is expected to continue to grow as the population ages and increases.

Ideally, replaced joints should withstand many years of everyday use, with revision (or repeat) surgeries needed no earlier than 15 to 20 years after the primary (or first) surgery.[3, 4] However, some patients require a revision within a short period of time. This has led to concerted efforts from joint replacement registries worldwide, including the Canadian Joint Replacement Registry (CJRR) at the Canadian Institute for Health Information (CIHI), to understand the trends and factors that contribute to revisions with the goal of minimizing the potentially avoidable ones.[5, 6]

This report focuses on early revisions of hip and knee replacement surgeries and their impacts on hospital systems and patients in Canada. For the purpose of this analysis, we define early revisions as those happening within 2 years of the primary surgery, as these revisions are more likely to be due to conditions surrounding the surgery or to the surgery itself.[7, 8] As such, these early revision surgeries can be viewed as largely avoidable, and represent actionable opportunities to improve quality of care (including patient experiences and outcomes), as well as to increase health system productivity and capacity.

Key findings

- **Out of 99,478 patients who had a primary hip or knee replacement due to OA in 2016–2017, a total of 2,012 had an early revision (within 2 years).**
  - This represents an early 2-year revision rate of 2.2% for hips and 1.9% for knees.
  - About 18% of these patients had multiple revisions of the same joint in the 2-year period.
- **In terms of the reasons for revision, over 30% of early revisions were due to prosthetic joint infection (PJI).**
  - Looking at revisions within 90 days of the primary surgery, PJI was responsible for 38% and 55% of these very early hip and knee revisions, respectively.
- **More patients with an early revision due to PJI had a recorded comorbidity, indicating the medical complexity of these patients.**
  - 24% of all early revision patients with PJI had a record of diabetes, compared with 13% of early hip revision and 17% of early knee revision patients without PJI.
- **In terms of hospital costs, overall, early revisions had much higher costs than the primary replacements. Cost differences were even greater for revisions due to PJI.**
  - For early revisions **excluding PJI**, the average cost per hospital stay was 1.6 times higher for hips ($15,647 versus $10,031 for primary) and 1.4 times higher for knees ($12,973 versus $9,184 for primary).
  - For early revisions **due to PJI**, the average cost per hospital stay was 2.3 times higher for hips ($23,125 versus $10,031 for primary) and 2.0 times higher for knees ($17,999 versus $9,184 for primary).
- **We estimate that the total cost burden for early revisions is over $42.1 million in direct inpatient costs annually.**
  - This does not include the cost of the initial surgery or other hospital visits. It also does not account for the negative impact on patients' experiences and outcomes (e.g., functioning, pain, quality of life), nor for the indirect costs to patients and their families.
- **These early revisions, particularly those due to PJI, are largely avoidable and present opportunities for targeted improvement at various levels, including health care systems and hospitals, surgeons and clinical staff, and patients.**

Methods

Using CIHI's Hospital Morbidity Database (HMDB) and National Ambulatory Care Reporting System (NACRS), we identified patients who had a primary hip or knee replacement in Canada from April 1, 2016, to March 31, 2017, and followed them for up to 2 years to identify any early revision surgeries. We included only primary replacements due to advanced OA to focus on surgeries that were initially planned and elective. Primary replacements not due to OA, particularly those due to fracture, tend to be urgent, more complicated cases with a different revision risk.[1, 9] For some analyses in this study, we focused on only the patient's first revision within the 2 years (e.g., to calculate revision rates and compare patient characteristics). For others, where indicated, we included all revisions, including re-revisions (e.g., when quantifying health system impacts).

The hospital cost estimates in this report are based on additional CIHI data sources and methodologies: 2017–2018 Canadian Management Information System Database (CMDB); Case Mix Group+ (CMG+) 2018 methodology; and Patient-Level Physician Billing Repository, which captures data from 5 provinces (Nova Scotia, Ontario, Manitoba, Saskatchewan and Alberta). For the cost estimates analysis, we looked at early revisions that occurred in 2017–2018; their primary surgeries were identified retrospectively. This methodology adjustment allowed us to leverage the most recent cost data available.

See Appendix A for more information.

An overall look at early revisions

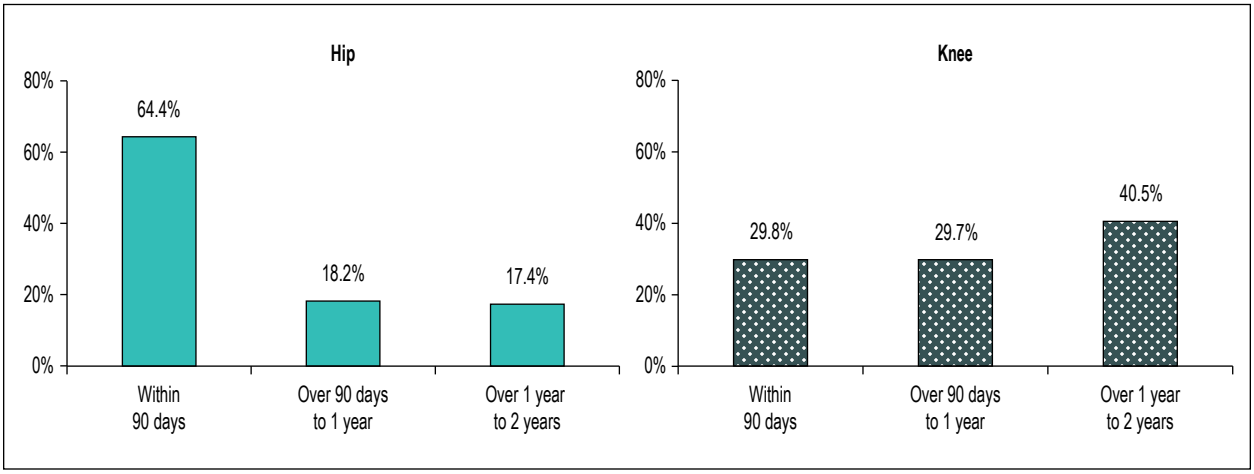
In 2016–2017, a total of 99,478 primary hip and knee replacement surgeries were performed in Canada to treat advanced OA. Of these patients, 2,012 had an early revision surgery within 2 years, counting only the first revision in the period.

- For patients with hip replacement, the 2-year revision rate was 2.2%, based on 811 early revisions of the 36,738 primary hip surgeries.
- For patients with knee replacement, the 2-year revision rate was 1.9%, based on 1,201 early revisions of the 62,740 primary knee surgeries.

The early (2-year) revision rate was 2.2% for patients with primary hip replacement and 1.9% for patients with primary knee replacement, where the original surgery was performed due to OA.

Figure 1 provides a breakdown of when these early revisions occurred in the 2-year period. Just over 64% of all early hip revisions took place within 90 days of the primary surgery. For knees, the distribution was more even, with almost 60% of early revisions occurring by 1 year after the primary surgery.

Figure 1 Time to first early revision of primary hip and knee replacements, Canada*



Note

* Based on 811 hip and 1,201 knee early revision surgeries that occurred within 2 years of the primary joint replacement surgery due to osteoarthritis in 2016–2017. Only the first revision is included.

Sources

Hospital Morbidity Database and National Ambulatory Care Reporting System, 2016–2017 to 2018–2019, Canadian Institute for Health Information.

Reasons for early revision

Figure 2 shows the most common reasons for revision, coded as the most responsible diagnosis for the hospitalization in the hospital documentation. A brief description of each reason is on the next page.

- For hip replacements, the top reason for early revisions within 2 years was PJI, which accounted for 32% of cases. This is followed by peri-prosthetic fracture at 14%, instability at 13% and aseptic loosening at 11%.
- For knee replacements, the top reason for early revision was also PJI, which accounted for 34% of cases. This is followed by instability at 15%, conditions such as pain and hemorrhage that occurred due to the prosthesis at 13% and aseptic loosening at 10%.

- Studies have shown that the closer the revision is to the primary surgery, the more likely it is to be related to the surgical technique or operating room conditions, rather than to the prosthesis or subsequent patient activities.[7, 8]
- For revisions that occurred within 90 days, we found that 38% and 55% of hip and knee revisions, respectively, were due to PJI. PJIs occurring so soon after surgery are likely related to surgical site infections,[10] which are one of the most common health care–associated infections and which lead to enormous costs for health systems and patients.[11]
- Patients whose revisions are due to PJI rather than mechanical complications also have a higher risk of 1-year mortality.[12]

Prosthetic joint infection (PJI) was the top reason for early revision surgery within 2 years of primary surgery, accounting for over 30% of early revisions.

For revisions occurring within 90 days of primary surgery, PJI had a higher contribution, being responsible for 38% of early hip and 55% of early knee revisions.

Defining top reasons for revision

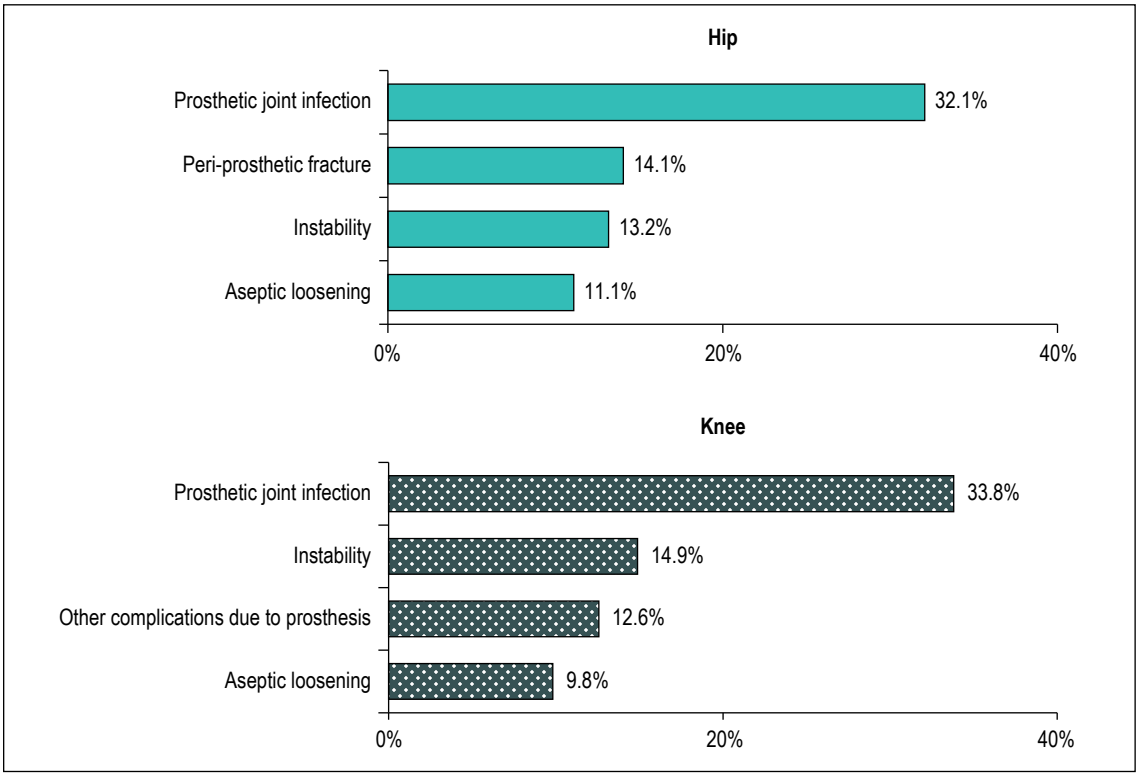
Prosthetic joint infection (PJI) occurs after a joint replacement surgery and involves infection in the area surrounding the prosthesis. Infection may occur at any time after surgery, either in hospital or after discharge. It can result in loosening and instability of the prosthesis.[13, 14]

Instability occurs when the structures that surround the joint do not work to maintain the articular surfaces. This may be a result of increased soft-tissue laxity, or improper positioning or alignment of the prosthesis.[13, 15]

Aseptic loosening is the failure of the bond between an implant and bone in the absence of infection.[13, 14]

Peri-prosthetic fracture is a broken bone that occurs around the implant of a joint replacement.[13, 14]

Figure 2 Top reasons for first early revision within 2 years of primary hip and knee replacement, Canada*



Notes

* Based on 811 hip and 1,201 knee early revision surgeries that occurred within 2 years of the primary joint replacement surgery due to osteoarthritis in 2016–2017. Only the first revision is included.

Reason for revision is based on the coded most responsible diagnosis for the hospital stay and the coded first problem for day surgery. *Other complications due to prosthesis* includes conditions such as embolism, fibrosis, hemorrhage and pain. Remaining reasons that are not shown include other specific mechanical reasons and other less common complications.

Sources

Hospital Morbidity Database and National Ambulatory Care Reporting System, 2016–2017 to 2018–2019, Canadian Institute for Health Information.

Patient characteristics of early revisions

Table 1 presents the characteristics of patients who had primary replacements and early revisions. Given the strong contributing role of PJI, we analyzed the early revisions according to whether they were due to PJI.

- The median age was similar across all groups and for both hip and knee replacements.
- The majority of patients were female across all groups, except for those with early knee revision due to PJI.
- Using the Charlson Comorbidity Index, based on diagnosis information recorded in the hospital record, patients with early revisions due to PJI had more comorbidities documented for both hip and knee replacements.
- 24% of patients with early hip and knee revisions due to PJI had diabetes recorded in the hospital record; this was a higher proportion compared with the other groups. This finding aligns with studies indicating that people with diabetes may be more prone to infection.[16, 17]

More patients with an early revision due to PJI had a recorded comorbidity, indicating the medical complexity of these patients. 24% of these patients had a record of diabetes, compared with 13% of early hip revision and 17% of early knee revision patients without PJI.

Table 1 Patient characteristics of primary hip and knee replacements and first early revisions (due to and excluding PJI), Canada*

Characteristic	Hip			Knee		
	Primary (n = 36,738)	Early revisions excluding PJI (n = 551)	Early revisions due to PJI (n = 260)	Primary (n = 62,740)	Early revisions excluding PJI (n = 795)	Early revisions due to PJI (n = 406)
Median age (years)	67	69	66	68	65	68
% female	53.7	60.8	51.5	60.2	58.7	41.6
% with comorbidity recorded (based on Charlson score)†	3.1	4.6	10.9	3.5	3.5	9.7
% with diabetes recorded†	11.8	12.7	23.9	17.3	17.0	24.1

Notes

* Based on 811 hip and 1,201 knee early revision surgeries that occurred within 2 years of the primary joint replacement surgery due to osteoarthritis in 2016–2017. Only the first revision is included.

† Comorbidity was assessed using the Charlson Comorbidity Index and was scored using a standard methodology. Diabetes was identified by the diagnosis code for diabetes in the hospital record. Refer to Appendix A for details.

PJI: Prosthetic joint infection.

Sources

Hospital Morbidity Database and National Ambulatory Care Reporting System, 2016–2017 to 2018–2019, Canadian Institute for Health Information.

A look at re-revisions

While most of our analyses focused on the first revision of a primary surgery, we found that there were cases of multiple revisions of the same joint (also known as re-revisions). For patients with an early revision of a hip or knee replacement, 82.4% had 1 revision, 11.2% had 2 and 6.4% had 3 or more within 2 years of the primary surgery. Patients undergoing an early hip or knee revision have a higher chance of having another revision within a year.[6]

Health system resource utilization

Given that early revisions are considered to be avoidable, we compared these early revisions (due to PJI or not) with primary replacements in terms of health system resource use (Table 2). To provide a more fulsome picture of the impact of early revisions on health care systems, we included all revisions (including multiple revisions) in this analysis, expanding the population to 1,035 early hip and 1,526 early knee revision surgeries.

- Overall, early revisions required more urgent acute care services, longer operating room (OR) times and longer inpatient length of stay (LOS) compared with initial joint replacement surgeries. When infection was the reason for revision, this gradient was accentuated even more.
- More of the early revisions — and particularly those due to PJI — were done in teaching hospitals compared with primary surgeries. Revisions are generally more complex surgeries and require more specialized care; therefore, they are more likely to be referred to teaching hospitals.[18]
- Early revisions of the hip due to PJI required almost 50% longer OR time compared with the primary replacement; OR time was 30% longer for knees.
- In terms of acute LOS, patients with early hip revision stayed over twice as long as primary replacement patients — 3 times longer when due to PJI. Patients with early knee revision due to PJI stayed over twice as long as primary replacement patients. For early knee revisions excluding PJI, the LOS was comparable to that for primary replacement patients.
- After discharge, nearly all patients with primary replacement were discharged home, whereas fewer patients with early revision were sent home directly. Even when patients are discharged home, most will still likely require follow-up with rehabilitation specialists, their primary care provider and others for some time after surgery.[19]

64% of early hip and 57% of early knee revisions due to PJI required urgent surgeries. This is compared with 46% and 18% for hip and knee, respectively, for reasons excluding PJI, and only 2% or less for the primary joint replacement surgery due to OA.

Table 2 Health system resource use for primary hip and knee replacements and early revisions (due to and excluding PJI), Canada*

Measure	Hip			Knee		
	Primary (n = 36,738)	Early revision excluding PJI (n = 605)	Early revision due to PJI (n = 430)	Primary (n = 62,740)	Early revision excluding PJI (n = 886)	Early revision due to PJI (n = 640)
% with urgent admission†	2.0	46.4	63.7	1.4	18.3	57.2
% in teaching hospital	38.4	43.6	48.4	31.0	38.3	43.1
Median OR time (minutes)‡	103	146	153	101	114	131
Median acute LOS (days)	3	6	9	3	3	8
% discharged home§	93.6	71.0	76.1	94.8	86.0	81.5

Notes

* Based on primary surgeries due to osteoarthritis performed in 2016–2017. Early revisions are defined as occurring within 2 years of the primary surgery. Patients may have more than one revision during the time period.

† Admission category applies to inpatient surgeries only.

‡ Surgeries performed in Quebec are not included because time of surgery is not available.

§ Discharged home includes discharged home with or without support from an external agency.

PJI: Prosthetic joint infection.

OR: Operating room.

LOS: Length of stay.

Sources

Hospital Morbidity Database and National Ambulatory Care Reporting System, 2016–2017 to 2018–2019, Canadian Institute for Health Information.

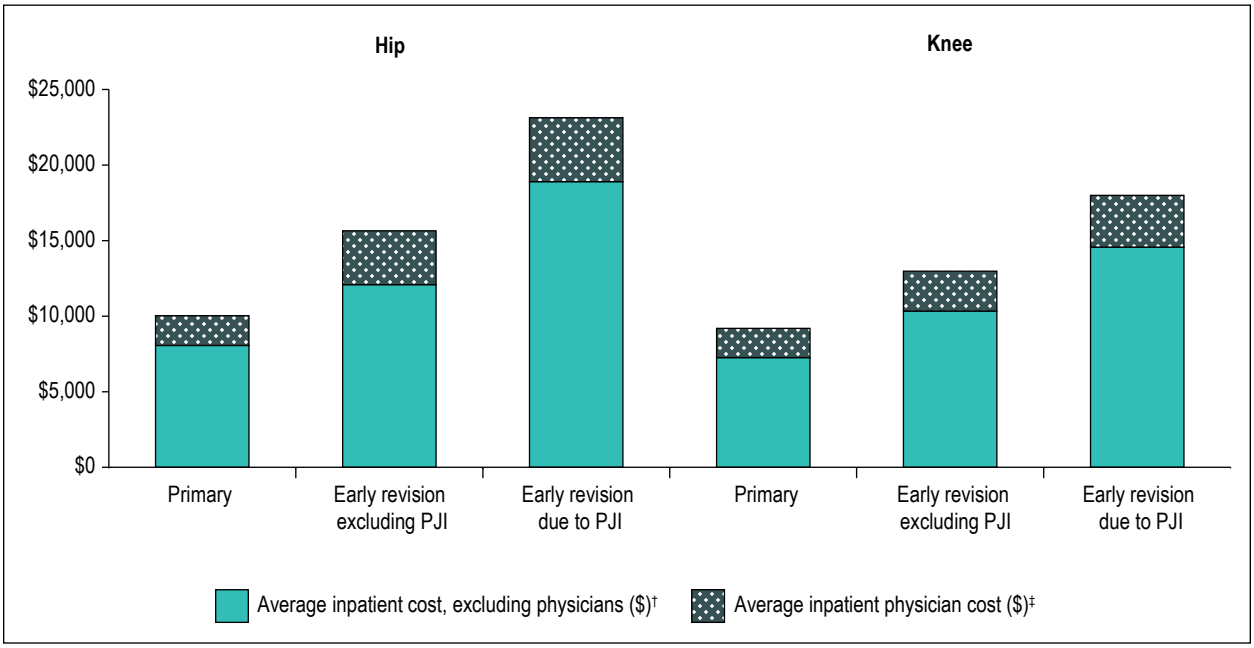
Hospital cost estimation

Figure 3 presents estimated average acute care inpatient costs for early revisions (due to PJI or another reason), as well as for primary replacement surgeries. For this analysis, we adjusted our methodology for patient follow-up to leverage the most recent functional cost data available. We also used a conservative approach to costing by limiting our cohort to relevant CMGs, which are standardized groupings of patients with similar complexity and resource utilization, and we included typical cases only (i.e., excluded deaths, sign-outs and transfers). See Appendix A for details.

- Overall, early revisions had a higher inpatient cost compared with initial joint replacement surgeries. When the early revision was due to PJI, the cost difference was even higher.
  - For early revisions excluding PJI, the total average cost per hospital stay was 1.6 times higher for hips ($15,647 versus $10,031 for primary) and 1.4 times higher for knees ($12,973 versus $9,184 for primary).
  - For early revisions due to PJI, the total average cost per stay was 2.3 times higher for hips ($23,125 versus $10,031 for primary) and 2.0 times higher for knees ($17,999 versus $9,184 for primary).
- Inpatient physician costs contributed about 20% of the total average cost per hospital stay across all surgery types.

Early revisions had a total average cost per hospital stay that was 1.6 times higher for hips and 1.4 times higher for knees compared with primary surgeries. When revisions were due to PJI, these ratios increased to 2.3 and 2.0 times for hips and knees, respectively.

Figure 3 Average estimated costs per hospital stay for primary hip and knee replacements and early revisions (due to and excluding PJI), Canada,* 2017–2018



Cost	Hip			Knee		
	Primary	Early revision excluding PJI	Early revision due to PJI	Primary	Early revision excluding PJI	Early revision due to PJI
Average inpatient cost, excluding physicians†	$8,053	$12,084	$18,909	$7,256	$10,338	$14,571
Average inpatient physician cost‡	$1,978	$3,563	$4,216	$1,928	$2,635	$3,428
Total average cost per hospital stay	**$10,031**	**$15,647**	**$23,125**	**$9,184**	**$12,973**	**$17,999**
Cost ratio (compared with primary surgery)	n/a	1.6	2.3	n/a	1.4	2.0

Notes

* Based on early revisions that occurred in 2017–2018 with a primary surgery that occurred within the previous 2 years. Only typical cases and those assigned to the following CMGs were included in the cost estimates: Hip Primary (n = 34,015); Hip Revision Without Infection (n = 312); Hip Revision With Infection (n = 226); Knee Primary (n = 57,893); Knee Revision Without Infection (n = 566); Knee Revision With Infection (n = 337). Since 95% of patients assigned to CMGs Hip/Knee Revision With Infection had PJI as the most responsible diagnosis recorded, we present the groups as revision due to PJI and revision excluding PJI.

† The inpatient cost estimate excluding physician costs is calculated by multiplying the national average Resource Intensity Weight (using CMG+ 2018) for each hospitalization by the national cost of a standard hospital stay.

‡ Physician cost is based on data from 5 provinces: Nova Scotia, Ontario, Manitoba, Saskatchewan and Alberta.

PJI: Prosthetic joint infection.

n/a: Not applicable.

Sources

Hospital Morbidity Database, Canadian Management Information System Database and Patient-Level Physician Billing Data Repository, 2017–2018, and Case Mix Group+ 2018, Canadian Institute for Health Information.

Table 3 shows the calculations used to determine the total cost burden of early revisions in terms of hospital costs, based on the inpatient cost estimates outlined previously. For each joint, we multiplied the total average cost per hospital stay by the number of early revisions based on the 2016–2017 cohort.

- Early revisions cost over $42.1 million in direct inpatient costs in total — $19.5 million for hips and $22.6 million for knees.
- It is important to note that these cost estimates are under-estimates, given that only typical cases are included in the average cost calculation. These estimates include only the hospitalization for an early revision surgery, not the initial surgery nor other hospitalizations for complications that did not lead to a revision surgery. For instance, patients with deep infection post-replacement surgery may require hospitalization but not necessarily a revision.[20]

Table 3 Calculation of total estimated cost burden of hospital stays for early hip and knee revisions within 2 years, Canada*

Cost category	Hip early revision (due to all reasons)	Knee early revision (due to all reasons)
Average inpatient cost, excluding physicians*	$14,952	$11,918
Average inpatient physician cost†	$3,853	$2,923
Total average cost per hospital stay*	$18,805	$14,841
Multiplied by Number of early revisions (including re-revisions) (based on 2016–2017 primary hip and knee replacements performed in Canada due to osteoarthritis)	1,035	1,526
Total hospital costs for early revisions	**$19,463,175**	**$22,647,366**

Notes

* Average cost estimates are based on only early revisions performed in 2017–2018 assigned to the following CMGs: Hip Primary; Hip Revision Without Infection; Hip Revision With Infection; Knee Primary; Knee Revision Without Infection; Knee Revision With Infection. Only typical cases are included.

† Physician billings are based on data from 5 provinces: Nova Scotia, Ontario, Manitoba, Saskatchewan and Alberta.

Sources

Hospital Morbidity Database, Canadian Management Information System Database and Patient-Level Physician Billing Data Repository, 2017–2018, and Case Mix Group+ 2018, Canadian Institute for Health Information.

Other patient impacts

The impacts of early revision surgery go well beyond the clinical and financial statistics that have been presented in this report. Not quantified in this report are additional patient costs, such as time taken off work, the rehabilitation period, caregiver burden, and any added physical and emotional stress. Patient-reported findings show that patients who undergo revision do not receive the same relief from many years of pain and limited mobility as patients who do not require a revision.[21, 22] For patients who require revision due to PJI, patient-reported studies show even worse pain, function and health-related quality of life than for those with no PJI.[23] Qualitative research studies on the experience of and impact on these patients indicate that revisions due to PJI can have broad and devastating impacts on patients, disrupting their regular activities and quality of life for the long term, causing stress, uncertainty and a loss of independence.[24]

Future directions

Based on estimates from our study, for every 100,000 primary hip and knee replacements performed in Canada to treat advanced OA, over 2,000 patients will require at least one early revision within 2 years. Considering that some of these patients undergo multiple revisions in this period, this number can increase to over 2,500 early revision surgeries within 2 years of the initial surgery. Our analyses describe the inpatient impacts of these revisions: based on a number of measures, these early revisions have multi-faceted impacts on hospitals and also place additional burdens and risks on patients, including quality of life impacts. These findings are even more accentuated when revisions are performed due to PJI.

Based on our early revision cohort, we calculated an early 2-year revision rate due to PJI of 0.7% for primary hip replacement patients and 0.6% for primary knee replacement patients. Given that prosthetic infection is considered largely preventable, these almost 660 early revisions due to PJI represent key opportunities to look for targeted efforts at the hospital, surgeon and patient levels. Examples include, for hospitals, consistently implementing stringent infection control practices pre-operatively (e.g., decolonization protocols), peri-operatively (e.g., sterilization, operating room controls) and post-operatively (e.g., antibiotic prophylaxis); for surgeons, keeping up to date on clinical best practices; and for patients, following post-surgery protocols and modifying their lifestyle-related risk factors (e.g., obesity, smoking, glycemic control).[16, 25] PJI is also reported as one of the leading causes of joint replacement revisions in registries in Canada and worldwide and presents a higher risk of readmission and death compared with revisions due to mechanical reasons (e.g., instability, aseptic loosening).[12, 26, 27]

Based on our fairly conservative estimates of average inpatient costs, these early revisions result in an estimated inpatient cost of over $42 million and an extra 25,349 acute care hospital days — all from largely avoidable revision surgeries. Again, these estimates do not take into account the cost of the initial surgery or any other hospitalizations that are not for revision surgery.[20] Clearly the ultimate goal is to get these surgeries right the first time so that these resources could be re-directed to other health system priorities, including potentially improving wait times for hip and knee replacements.[28]

In the future, CIHI will be able to report on standardized patient-reported data on these surgeries. We are collecting data on acute care patient experiences through the Canadian Patient Experiences Reporting System,[29] we have a national program on hip and knee replacement patient-reported outcome measures (PROMs)[30] and we participate in international hip and knee PROMs reporting initiatives.[31] The integration of this patient-reported data, in addition to other data on, for example, prosthesis characteristics from CJRR, health care utilization and costs outside of the hospital, will support patient-centred and value-based health care delivery and analysis for hip and knee replacement patients.

The Canadian Joint Replacement Registry

CJRR collects surgical and prosthesis information about hip and knee replacements performed in Canada. Canada's only pan-Canadian medical device registry, it was launched in 2001 as a collaborative effort between CIHI and the Canadian Orthopaedic Association. CJRR information complements demographic and administrative information captured in other CIHI databases: the Discharge Abstract Database–Hospital Morbidity Database (DAD-HMDB) and NACRS. CJRR regularly reports on cumulative revision risk by selected risk factors such as sex, age, type of replacement, surgical technique and implant characteristics.[1] Many joint replacement registries around the world have been reporting on cumulative revision risk for hip and knee replacements for many years.[32]

For information about the CJRR program and coverage, please visit the CJRR page of CIHI's website.

Appendix A: Methodology notes

Main study population

Using CIHI's HMDB and NACRS, we identified all primary hip and knee replacements that took place across Canada from April 1, 2016, to March 31, 2017. Only primary replacements that had a diagnosis of OA were considered (excluding, for example, those who had a diagnosis of fracture recorded on the abstract). This resulted in a primary replacement cohort of 99,478 patients. Of these, nearly all (98%) were considered to be planned (elective) surgeries.

We followed up the cohort of patients and identified all subsequent revision surgeries occurring within 2 years (730 days) for inclusion in this study. The linkage was based on the patient's encrypted health card number and jurisdiction issuing health card number, the joint type and the replacement side. 37 surgeries were excluded because they recorded both a primary and revision surgery or 2 revision surgeries during the same surgical episode.

The final number of early revisions for our primary replacement cohort was 2,012 first revisions, with 99.8% being unique patients. When re-revisions were included, the number of early revisions increased to 2,561.

Reason for revision was based on the most responsible diagnosis for the hospital stay as coded in the HMDB and on the first problem for the day surgery as coded in NACRS.

Comorbidity was assessed using the Charlson Comorbidity Index and was scored using a standard methodology.[33] Diabetes was identified by diagnosis of diabetes in the hospital record.

Table A1 Identifying procedures and diagnoses used in this analysis

Procedure or diagnosis	ICD-10-CA or CCI code
Primary hip replacements	1VA53, 1SQ53 (excluding primary cement spacers) with status attribute = P
Primary knee replacements	1VP53, 1VG53 (excluding primary cement spacers) with status attribute = P
Osteoarthritis	M16, M17
Fracture	S72000, S72001, S72010, S72011, S72080, S72081, S72090, S72091, S72100, S72101, S72200, S72201
Diabetes	E10, E11, E13, E14
Revision hip replacements	1VA53, 1SQ53 with status attribute = R; cement spacers included (considered the first step in a 2-step revision)
Revision knee replacements	1VP53, 1VG53 with status attribute = R; cement spacers included (considered the first step in a 2-step revision)

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

Hospital cost estimation

The inpatient cost cohort is based on 1,441 hospitalizations with 1 unilateral hip or knee revision surgery in the HMDB in 2017–2018, where the primary surgery due to OA had occurred within the 2 previous years (identified in the HMDB and NACRS from 2015–2016 to 2017–2018). Costs are presented by CMG (see below). Only typical cases are included. Typical cases represent the completion of a full course of treatment at a single hospital, while atypical cases denote 1 of 4 categories: deaths, sign-outs, transfers and long-stay outliers.

Table A2 CMGs used in this analysis

Type of replacement	CMG
Primary replacement	320 — Unilateral Hip Replacement 321 — Unilateral Knee Replacement
Early revision excluding PJI	317 — Revised Hip Replacement Without Infection 319 — Revised Knee Replacement Without Infection
Early revision due to PJI*	316 — Revised Hip Replacement With Infection 318 — Revised Knee Replacement With Infection

Notes

* The vast majority of cases (93.8% of hip and 95.0% of knee) had a most responsible diagnosis in hospital of infection and inflammatory reaction due to hip/knee prosthesis (prosthetic joint infection).

PJI: Prosthetic joint infection.

Inpatient cost estimates, excluding physician costs, are calculated by multiplying the Resource Intensity Weight (RIW) for each hospitalization by the national cost of a standard hospital stay (CSHS).[34] RIW is determined from the 2017–2018 HMDB using the CMG+ 2018 methodology. The CSHS is determined from the 2017–2018 CMDB using the CMG+ 2018 methodology. Functional cost data from Quebec was mapped to the CMDB.

Physician costs estimates are computed using the physician claims associated with the hospitalization. For each hospitalization, the associated physician cost is given by summing the costs for each claim that occurred during the inpatient stay. Physician costs are not assigned to hospitalizations unless both a surgical and anesthetic claim are present. The average physician cost is given by taking the average over all typical cases. Physician costs presented in this study were based on data from Nova Scotia, Ontario, Manitoba, Saskatchewan and Alberta.

Appendix B: Text alternatives for figures

Figure 1 Time to first early revision of primary hip and knee replacements, Canada*

Time from primary surgery to first revision	Hip	Knee
Within 90 days	64.4%	29.8%
Over 90 days to 1 year	18.2%	29.7%
Over 1 year to 2 years	17.4%	40.5%

Note

* Based on 811 hip and 1,201 knee early revision surgeries that occurred within 2 years of the primary joint replacement surgery due to osteoarthritis in 2016–2017. Only the first revision is included.

Sources

Hospital Morbidity Database and National Ambulatory Care Reporting System, 2016–2017 to 2018–2019, Canadian Institute for Health Information.

Figure 2 Top reasons for first early revision within 2 years of primary hip and knee replacement, Canada*

Reason for revision: hip	Percentage of total
Prosthetic joint infection	32.1%
Peri-prosthetic fracture	14.1%
Instability	13.2%
Aseptic loosening	11.1%

Reason for revision: knee	Percentage of total
Prosthetic joint infection	33.8%
Instability	14.9%
Other complications due to prosthesis	12.6%
Aseptic loosening	9.8%

Notes

* Based on 811 hip and 1,201 knee early revision surgeries that occurred within 2 years of the primary joint replacement surgery due to osteoarthritis in 2016–2017. Only the first revision is included.

Reason for revision is based on the coded most responsible diagnosis for the hospital stay and the coded first problem for day surgery. *Other complications due to prosthesis* includes conditions such as embolism, fibrosis, hemorrhage and pain. Remaining reasons that are not shown include other specific mechanical reasons and other less common complications.

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