



# Hip and Knee Replacements in Canada, 2014–2015

Canadian Joint Replacement Registry  
Annual Report



Canadian Institute  
for Health Information

Institut canadien  
d'information sur la santé

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- Dr. Michael Dunbar (Co-Chair), Queen Elizabeth II Health Sciences Centre, Nova Scotia
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- Greg Webster, Director, Acute and Ambulatory Care Information Services

## Key findings

*Hip and Knee Replacements in Canada, 2014–2015: Canadian Joint Replacement Registry Annual Report* provides updated information on hip and knee replacement surgeries performed in Canada, including, for the first time, cumulative revision risk estimates based on data from the CJRR. This revision risk analysis, which involved following each primary surgery up to 3 years, included more than 163,000 primary surgeries from provinces that are mandated to report to CJRR (Ontario, Manitoba and British Columbia).

**Over the past 5 years, the number of hip and knee replacement surgeries performed in Canada has continued to increase.**

- In 2014–2015, there were 51,272 hip replacement surgeries and 61,421 knee replacement surgeries performed in Canada, which are increases of 20.0% and 20.3%, respectively, compared with 5 years ago.
- Hip and knee joint replacements are one of the most effective ways to reduce joint pain and improve functioning for patients with advanced hip and knee problems, most commonly resulting from osteoarthritis.

**Annually, more than 8,500 hip and knee revision surgeries are performed in Canada.**

- In 2014–2015, there were 4,347 hip and 4,185 knee revision surgeries performed in Canada, which represented 8.5% and 6.8% of all hip and knee replacement surgeries that year, respectively.
- While revisions may represent a relatively small proportion of all joint replacement surgeries, these types of surgeries are more complex than primary surgeries and have implications for both the patient and the health care system, such as reduced function, longer patient recovery time and higher procedure costs.
- Examining risk factors for early revision can inform clinical best practices for joint replacement patients.

**For hip replacements, age and use of cementless femoral fixation appear to be risk factors for having an early revision surgery (i.e., less than 3 years after primary joint replacement).**

- Among hip replacement patients with osteoarthritis, older patients were at a significantly higher risk for early revision surgery compared with younger patients.
- Among patients who had a hip replacement after a hip fracture, the cumulative revision rate was significantly higher for those who had a cementless fixation (3.8%) than for those with a cemented fixation (2.3%).

**Age, sex and extent of knee replacement significantly influence the risk of having an early knee revision surgery (i.e., less than 3 years after primary joint replacement).**

- Compared with a total knee replacement surgery, a partial knee replacement surgery was significantly more likely to result in an early revision.
- Males had a significantly higher revision rate than females, at 2.0% versus 1.3%, respectively.
- Patients younger than 55 had a higher revision rate than patients in older age groups.

## About this report

*Hip and Knee Replacements in Canada, 2014–2015: Canadian Joint Replacement Registry Annual Report* provides an overview of key statistics related to hip and knee replacement surgeries performed in Canada. For the first time in this report, we present cumulative revision risk estimates for hip and knee replacements based on Canadian data. Reducing the need for early revisions offers substantial patient and cost-related benefits and is one of the primary objectives of international orthopedic registries, including those from Australia, the United Kingdom and Sweden.<sup>1–3</sup>

The companion data tables for this report are available on CIHI's website at [www.cihi.ca/cjrr](http://www.cihi.ca/cjrr) (Hip and Knee Replacements in Canada: 2014–2015 Quick Stats). These data tables also include provincial-level results.

Please direct any questions or feedback to CIHI's CJRR team at [cjrr@cihi.ca](mailto:cjrr@cihi.ca).

## The Canadian Joint Replacement Registry

CJRR is a pan-Canadian source of information about hip and knee replacements. It was launched in 2001 as a collaborative effort between the Canadian Institute for Health Information (CIHI) and the Canadian Orthopaedic Association. CJRR was established to record and analyze clinical information and outcomes of primary and revision hip and knee replacements over time.

CJRR provides patient and prosthesis information that complements demographic and administrative information captured in other CIHI databases, specifically in the Discharge Abstract Database (DAD), the Hospital Morbidity Database (HMDB) and the National Ambulatory Care Reporting System (NACRS).

As of 2014–2015, 3 provinces have mandated hip and knee replacement submissions to CJRR (Ontario, Manitoba and British Columbia), as have 2 regions in Saskatchewan (Regina Qu'Appelle Health Region and Saskatoon Health Region). Submission for all other provinces was voluntary during that time. As shown in Appendix 1, coverage for 2014–2015 was 71.1% nationally, with variations by province and territory. Nova Scotia began implementing a mandated submission to CJRR beginning in 2016–2017. Mandatory submission from all jurisdictions would be the most effective way to ensure comprehensive capture of prosthesis and outcome information for all hip and knee replacement patients in Canada.

More information on CJRR can be found at [www.cihi.ca/cjrr](http://www.cihi.ca/cjrr).

## Hip replacement surgeries in Canada

### Summary of annual statistics

**Over the past 5 years, the number of hip replacement surgeries performed in Canada has continued to increase.**

- In 2014–2015, there were 51,272 hip replacements performed in Canada, a 20.0% increase from 5 years ago when there were 42,713 of these surgeries.
- The age-standardized rates have also continued to increase in recent years. In 2014–2015, the rate was 171 per 100,000 population age 18 and older — 6.9% higher than in 2010–2011 (160 per 100,000 population age 18 and older).
- Overall, two-thirds of patients who had a hip replacement were age 65 and older. Among females who had a hip replacement, 73.0% were at least 65 years old, compared with 59.1% of males.



- The median length of stay (LOS) in hospital was 4 days. Among female patients, the median LOS was 4 days; for males, it was 3 days.
- The most common reasons for having a primary hip replacement were degenerative arthritis (74.1%) and acute hip fracture (14.9%).

**In 2014–2015 in Canada, 4,347 hip revision surgeries were performed, representing 8.5% of all hip replacement surgeries done that year.**

- While revisions may represent a relatively small proportion of all joint replacement surgeries, these types of surgeries are more complex than primary surgeries and have implications for both the patient and the health care system, such as reduced function,<sup>4, 5</sup> longer patient recovery time<sup>4, 5</sup> and higher procedure costs.<sup>6</sup>
- Among all hip revisions reported in CJRR for 2014–2015, the femoral head was by far the most common component replaced<sup>i</sup> (91.9%), while the femoral component was the least common (49.3% of revision procedures). Acetabular components were replaced in 53.8% of reported revisions, while 73.7% of revisions required the acetabular liners to be changed.
- The most common reason for revision was aseptic loosening (28.0%), followed by instability (16.5%) and infection (15.0%).<sup>ii</sup>

Jurisdictional-level results and annual trends, as well as additional clinical- and hospital-related information (e.g., diagnosis grouping) can be found in the companion data tables at [www.cihi.ca/cjrr](http://www.cihi.ca/cjrr) (Hip and Knee Replacements in Canada, 2014–2015 Quick Stats).

## Examining risks for hip revision surgery

Figures 1 to 4 provide revision risk data based on survival analyses related to hip replacement surgeries. From 2012–2013 to 2014–2015, there were 68,954 primary hip replacement surgeries reported to CJRR from Ontario, Manitoba and British Columbia (the 3 CJRR-mandated provinces). Only data from CJRR-mandated provinces was included to ensure a high hip replacement coverage rate for this analysis. Time to first revision was determined based on revisions identified in the Discharge Abstract Database (DAD), CIHI's primary hospitalization database. This was done to ensure capture of the first occurrence of a revision. More details regarding the methodology are presented in Appendix 2. Among hip replacement patients, surgeons identified degenerative arthritis (also known as osteoarthritis) and acute hip fracture as the most common most responsible diagnoses resulting in the need for surgery. Because there are clinical differences between these 2 patient groups as well as different treatment pathways,<sup>7, 8</sup> we analyzed their cumulative revision risks separately.

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- i. 4 basic components (or implant parts) are used for hip replacements: acetabular component, acetabular insert/liner, femoral component and femoral head. Throughout this report, the term "component replaced" refers to components that replace existing artificial implants, as in the case of revision procedures.
  - ii. For this report, to determine the most common reasons for revision, only procedures associated with a specific reason for revision were included (i.e., those with "Other" indicated as the reason for revision were excluded), and "Infection" includes only single-stage revisions and the first stage of a 2-stage revision.

## A closer look at patients with degenerative arthritis

During the time period analyzed, 49,924 patients (72.4%) had a primary total hip replacement due to degenerative arthritis. There were 826 (1.7%) first revisions identified.<sup>iii</sup> We looked at early risk of revision by 2 important demographic factors, gender and age, which are readily available in our data and identified as potential risk factors for having a revision surgery.

### **Gender does not significantly impact early revision risk.**

- Of all primary total hip replacements due to degenerative arthritis, more than half (55.3%) were performed on female patients.
- There was no significant difference in the cumulative rate of early revisions for females and males (Figure 1). The overall cumulative revision risk was relatively low, with a 2-year rate of 2.0% and 1.8%, respectively.

### **Age appears to be an influencing factor for early revision risk.**

- One-third of replacements (33.2%) were performed in patients age 65 to 74, followed by those 75 and older (27.5%) and 55 to 64 (26.6%).
- The lowest share of total hip replacements for degenerative arthritis was found among patients younger than 55 (12.7%).
- Compared with the other age groups studied, patients age 75 and older had a significantly higher risk of early revision (Figure 2).
- 2 years post-surgery, the risk curves appear to be converging, which suggests that while older patients are at a higher risk for early complications, their risk over time is similar to that of the younger population. The relative decrease in revision risk in the oldest population could be a result of the competing risk of death.

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iii. Only the first subsequent revision was considered. The data sources for revision surgeries were DAD and NACRS.

## A closer look at patients who had a hip fracture

During the 3-year period analyzed, among the 10,250 primary hip replacements performed to treat acute hip fractures, 283 (2.8%) required at least one revision surgery. For these patients, the major factors contributing to revision are based on the type of arthroplasty surgery performed and the type of femoral fixation method<sup>iv</sup> used.

### **Early revision risks were similar for primary total hip replacement and partial replacement, the 2 leading procedures used for treating hip fractures requiring joint replacements.**

- 88.4% of replacement surgeries to treat hip fractures were partial hip replacements, with the use of bipolar prostheses being more common (65.0%) than monopolar ones. The remainder of the replacement surgeries involved a total hip replacement.
- At the 2-year mark, the cumulative revision rate for total hip replacement was 3.1%; the rates were 3.5% for bipolar partial replacement and 3.3% for monopolar partial hip replacement (Figure 3).

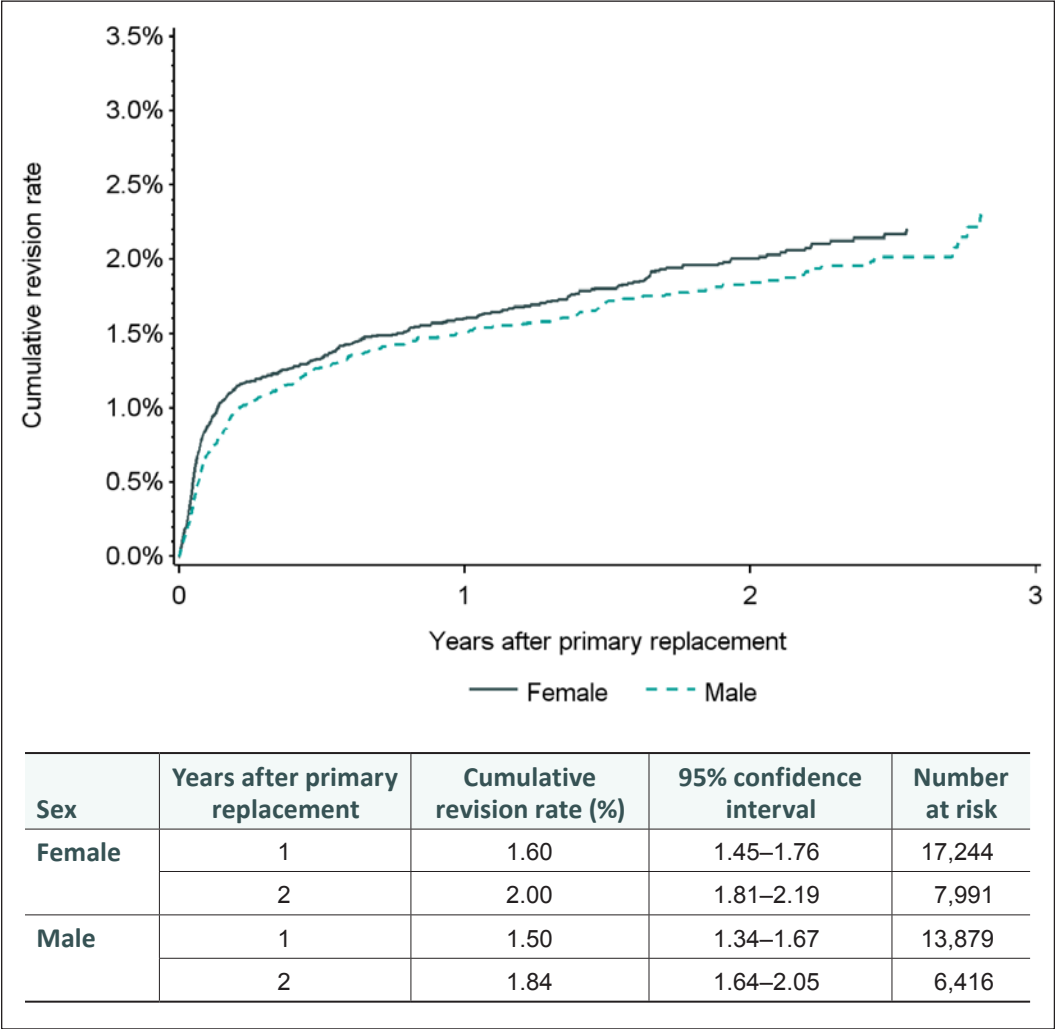
### **Method of femoral fixation appears to have a significant impact on short-term revisions for primary hip replacements.**

- Cementless femoral fixation was far more common than cemented (72.1% versus 27.9%).
- The cumulative revision rate was higher for cementless fixation within the first 2 years after the primary replacement (Figure 4).
- Cemented femoral fixation yielded a 2.3% revision rate at 2 years post-fracture, while cementless stood at 3.8%.
- Of note, for partial hip arthroplasty, fixation method for the femoral stem was unavailable for 16.7% of the 9,065 patients with a diagnosis of acute hip fracture.

iv. To enable the identification of femoral fixation method, femoral component catalogue numbers were linked to implant product barcodes in the International Consortium of Orthopaedic Registries (ICOR) universal implant product library.<sup>9</sup> Cement fixation attributes (cemented versus cementless) for femoral components used were obtained from the library.

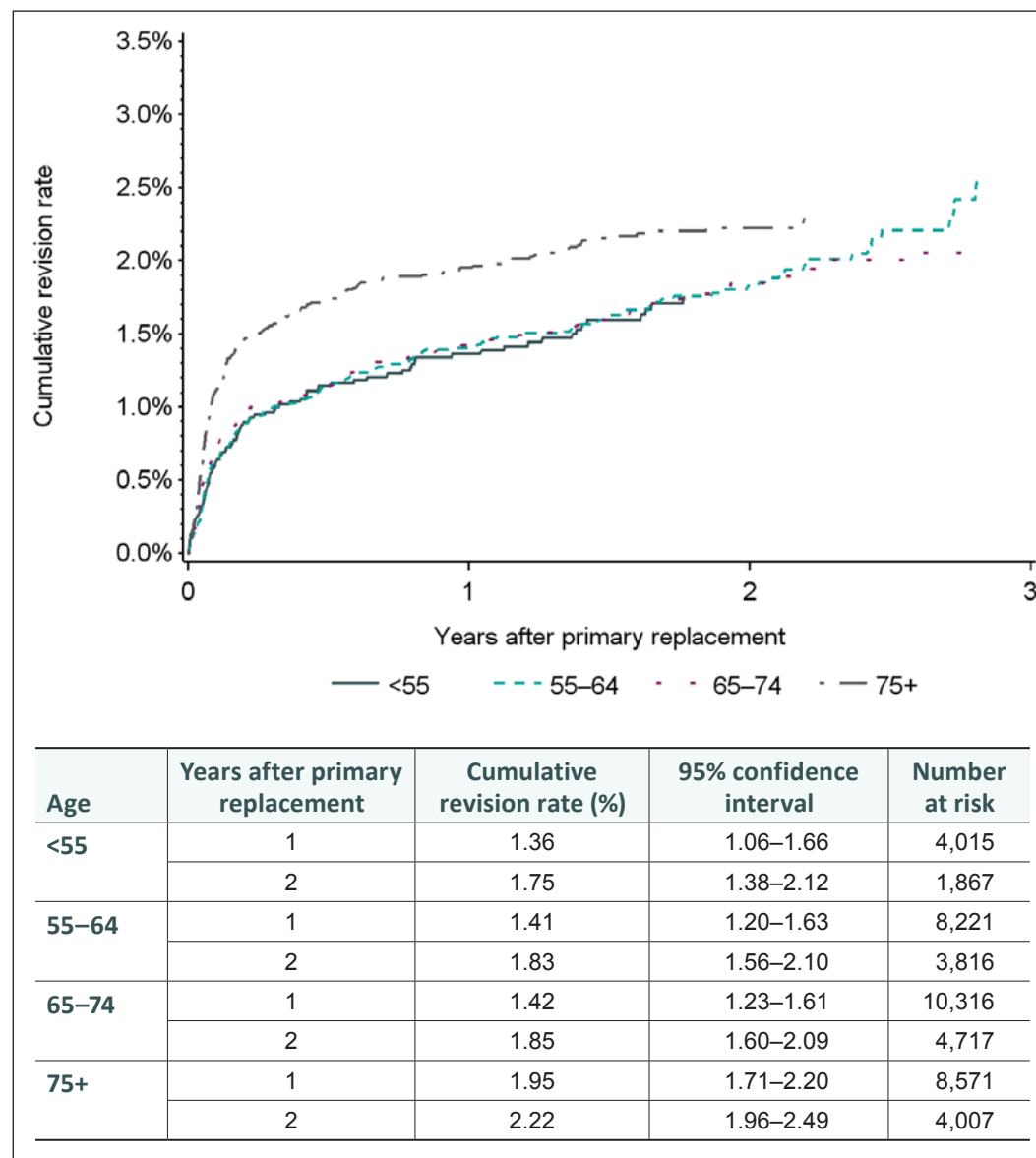
## Hip revision risk figures

**Figure 1** Cumulative revision rate for primary total hip replacement by sex (primary diagnosis of degenerative arthritis), 2012 to 2014



**Sources**  
Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only) and Discharge Abstract Database, 2012–2013 to 2014–2015, Canadian Institute for Health Information.

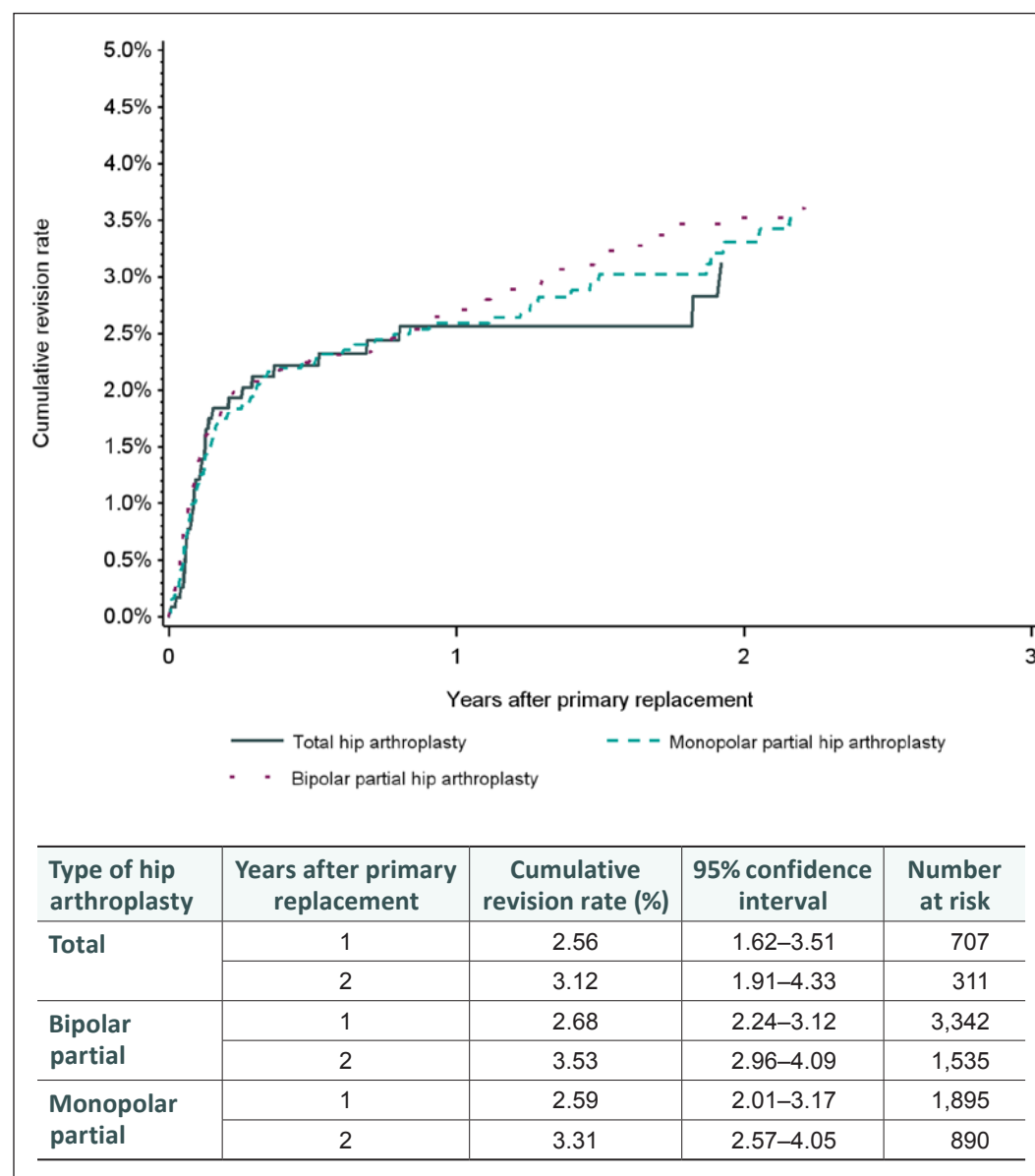
**Figure 2** Cumulative revision rate for primary total hip replacement by age group (primary diagnosis of degenerative arthritis), 2012 to 2014



**Sources**

Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only) and Discharge Abstract Database, 2012–2013 to 2014–2015, Canadian Institute for Health Information.

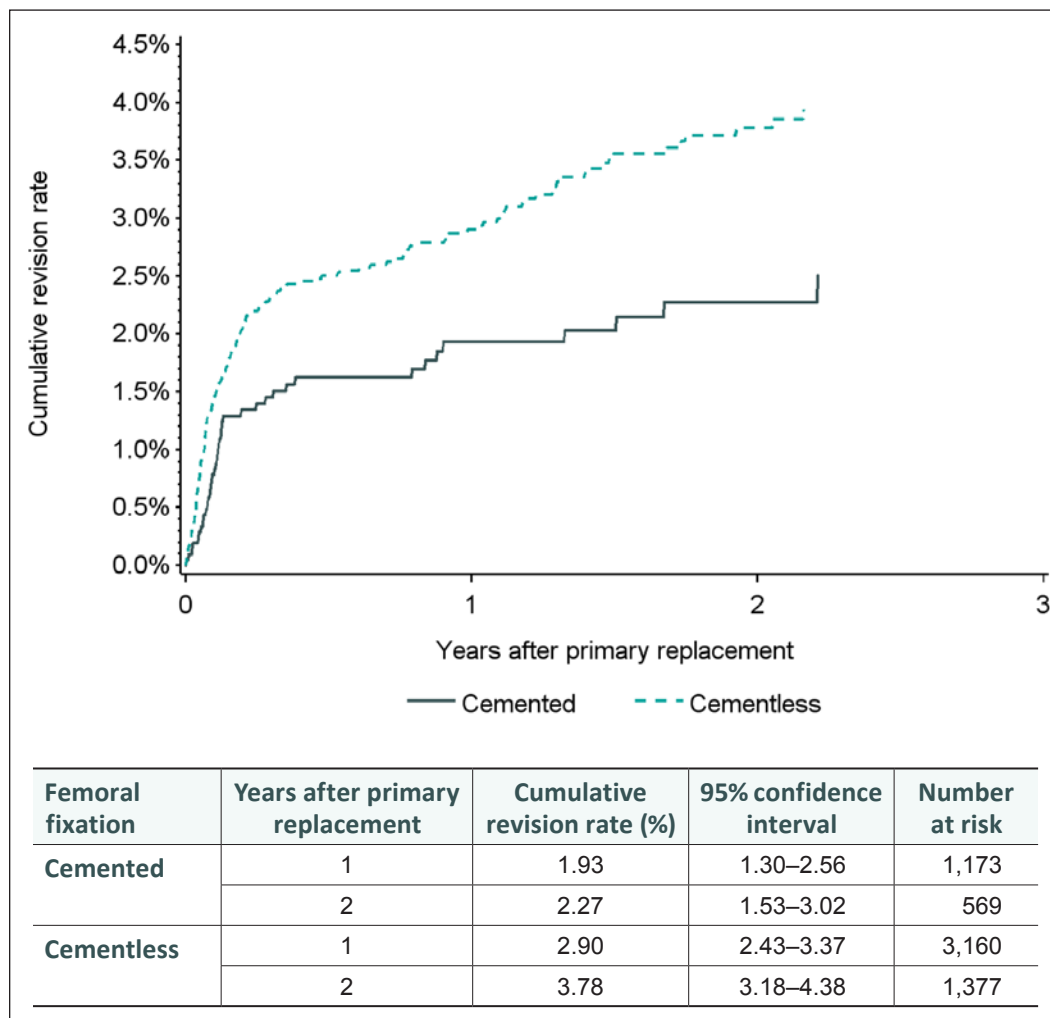
**Figure 3** Cumulative revision rate for primary hip replacement by type of procedure (primary diagnosis of acute hip fracture), 2012 to 2014



#### Sources

Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only) and Discharge Abstract Database, 2012–2013 to 2014–2015, Canadian Institute for Health Information.

**Figure 4** Cumulative revision rate for primary partial hip replacement by femoral fixation (primary diagnosis of acute hip fracture), 2012 to 2014



#### Sources

Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only) and Discharge Abstract Database, 2012–2013 to 2014–2015, Canadian Institute for Health Information; International Consortium of Orthopaedic Registries–International Society of Arthroplasty Registries (ICOR-ISAR). Global Arthroplasty Product Library. July 29, 2015 version.

# Knee replacement surgeries in Canada

## Summary of annual statistics

**Over the past 5 years, the number of knee replacement surgeries performed in Canada has continued to increase.**

- In 2014–2015, there were 61,421 knee replacements performed in Canada, which is a 20.3% increase compared with 5 years ago when there were 51,066 knee replacement surgeries.
- The age-standardized rate has remained relatively steady over the last 3 years, at 205 hospitalizations per 100,000 population age 18 and older.
- Females continue to have a higher rate for knee replacements compared with men (236 versus 172 per 100,000 adult population). Among patients undergoing a knee replacement, the age distribution by sex was very similar.
- More than half of patients were age 65 and older, with a similar percentage of female and male patients among this population (60.1% and 61.2%, respectively).
- The median LOS in hospital was 3 days, with similar results for female and male patients.
- Degenerative arthritis was by far the most common diagnosis grouping indicated by surgeons (97.9%).

**In 2014–2015 in Canada, 4,185 knee revision surgeries were performed, representing 6.8% of all knee surgeries done that year.**

- While revisions may represent a relatively small proportion of all joint replacement surgeries, these types of surgeries are more complex than primary surgeries and have implications for both the patient and the health care system, such as reduced function,<sup>4, 5</sup> longer patient recovery time<sup>4, 5</sup> and higher procedure costs.<sup>6</sup>
- Among all knee revisions reported to CJRR for 2014–2015, the tibial insert was the most common component replaced (87.7%) and the patellar component was the least common (27.3%). 67.6% of femoral components and 62.1% of tibial components were replaced.
- The most common reasons for revision were aseptic loosening (28.7%), infection (23.4%) and instability (15.9%).<sup>v</sup>

Jurisdiction-level results and annual trends, as well as additional clinical and hospital-related information (e.g., diagnosis grouping) can be found in the companion data tables at [www.cihi.ca/cjrr](http://www.cihi.ca/cjrr) (Hip and Knee Replacements in Canada: 2014–2015 Quick Stats).

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v. For this report, to determine the most common reasons for revision, only procedures associated with a specific reason for revision were included (i.e., those with “Other” indicated as the reason for revision were excluded), and “Infection” includes only single-stage revisions and the first stage of a 2-stage revision.



## Examining risks for knee revision surgery

Figures 5 to 7 provide revision risk data based on survival analyses related to knee replacement surgeries. From 2012–2013 to 2014–2015, there were 94,771 primary knee replacement surgeries reported to CJRR from Ontario, Manitoba and British Columbia (the 3 CJRR-mandated provinces). Only data from CJRR-mandated provinces was included to ensure a high coverage rate. Time to first revision was determined based on revisions identified in the DAD, CIHI's primary hospitalization database. This was done to ensure capture of the first occurrence of a revision. More details regarding the methodology are presented in Appendix 2.

We looked at the early revision risk for the main types of knee replacements, which can be broadly classified into 2 categories: partial and total (complete). A total (complete) knee replacement typically involves the medial and lateral compartments of the knee, with or without resurfacing of the patella. A partial knee replacement typically involves one of the medial, lateral or patellofemoral compartments of the knee. Because patients who require these surgeries are commonly diagnosed with degenerative arthritis, we focused our analyses on this population.

### Total versus partial knee replacements

**The early revision risk for all types of partial knee replacements (medial, lateral and patellofemoral) was significantly higher than for total knee replacements.**

- Among all knee replacements performed in the study time period, the vast majority were total knee replacements (94.8%), with the remaining 5.2% being partial knee replacements. Following a total knee replacement, overall, 1.2% required an early revision; following a partial knee replacement, the overall revision rate was 3.0%.
- Looking at the cumulative revision rate, total knee replacements had the lowest rate at 1.6% at the 2-year mark (Figure 5).
- Among the partial knee replacements, medial was the most common approach (89.2 %), followed by lateral (6.5%) and then patellofemoral (4.3%).
- Of the 3 types of partial knee procedures, the partial medial knee replacement had the lowest revision rate (3.6%) 2 years post-surgery, compared with partial lateral (6.5%) and patellofemoral (6.9%).

## A closer look at patients with degenerative arthritis

Among all patients who underwent knee replacement procedures in this analysis, nearly all were diagnosed with degenerative arthritis as the most responsible diagnosis (97.9%). Risk factors of age and sex were investigated in terms of their influencing factors on early revision.

Out of 87,838 primary total knee replacements for degenerative arthritis completed in the 3 years of interest, 1,035 (1.2%) required at least one revision during the study period.

### **The early revision risk was significantly higher for males than for females.**

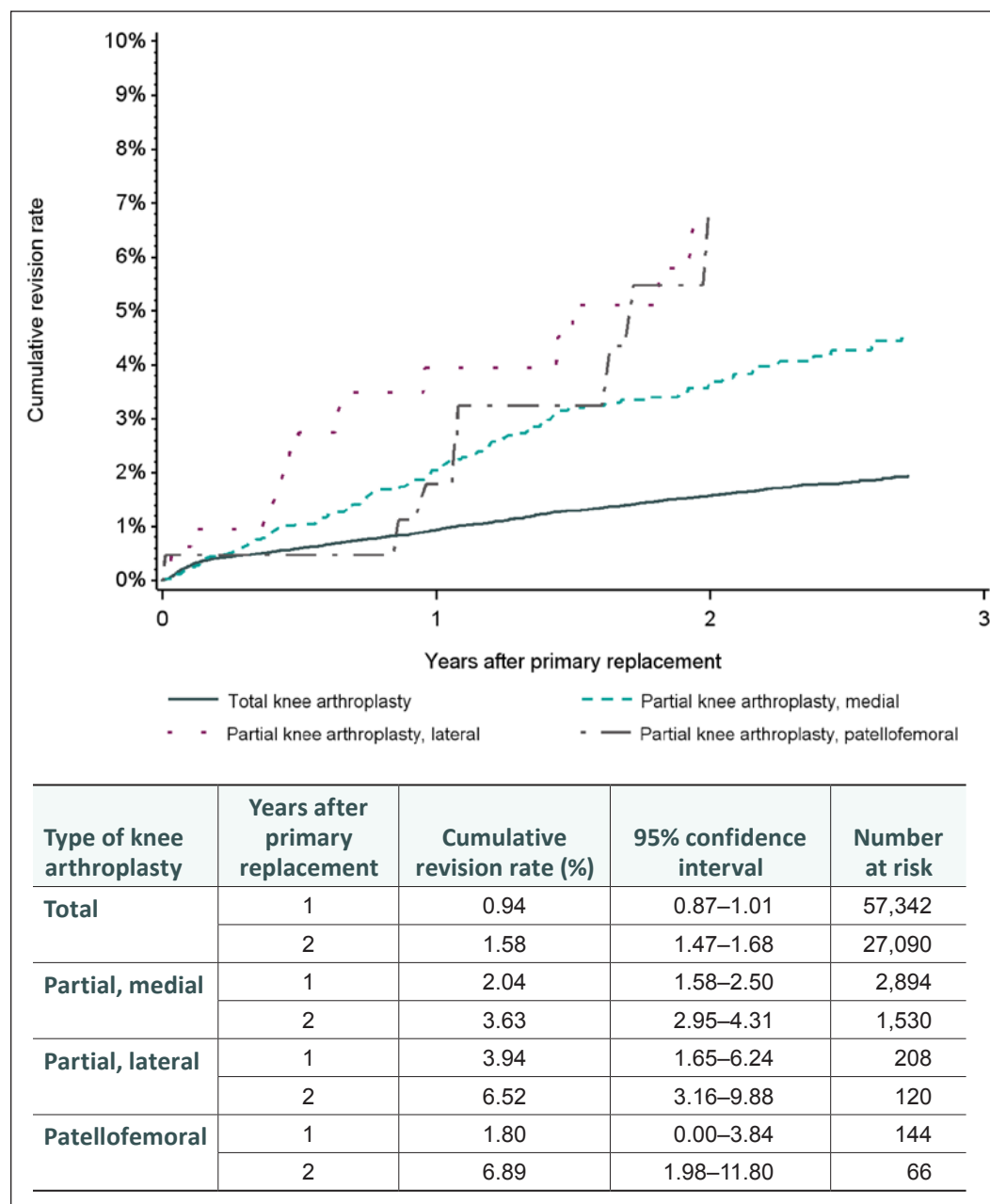
- The majority of primary total knee replacements (61.6%) were performed in female patients.
- However, 2 years after the primary knee replacement, the revision rate for males was 2.0%, while for females, it was 1.3% (Figure 6).

### **Age was a significant risk factor affecting the early revision risk for knee replacements.**

- The majority of primary total knee replacements for degenerative arthritis were performed in patients age 65 to 74 (37.5%), followed by age 55 to 64 (29.7%) and those age 75 and older (24.8%). The youngest age group (those younger than 55) had the lowest number of surgeries (8.1%).
- The highest revision risk was observed among patients younger than 55 (2.6% at 2 years). Early revision rates for seniors (age 65+) were different from the rates for those younger than 65. The cumulative revision rates for seniors age 65 and older were similar (Figure 7).

## Knee revision risk figures

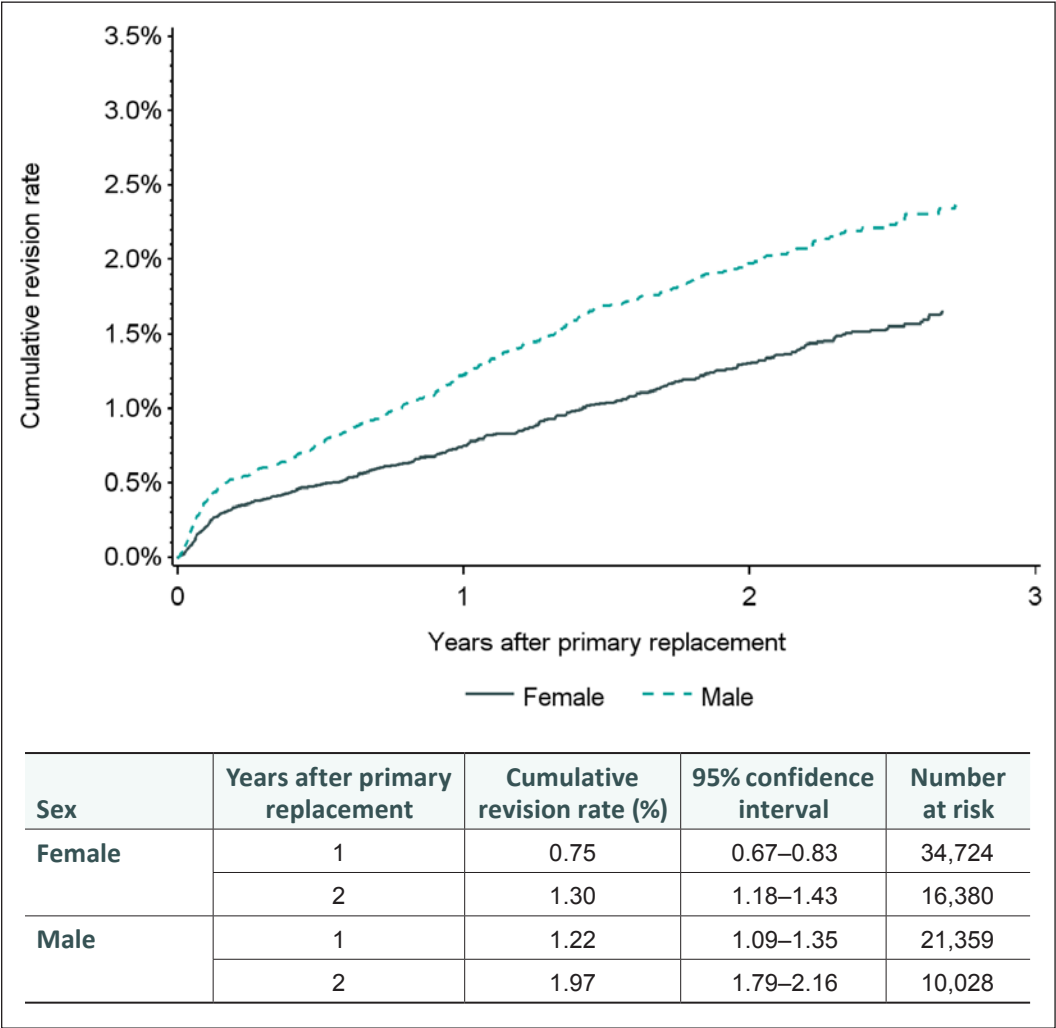
**Figure 5** Cumulative revision rate for primary total and partial knee replacement by type of procedure (all diagnoses), 2012 to 2014



### Sources

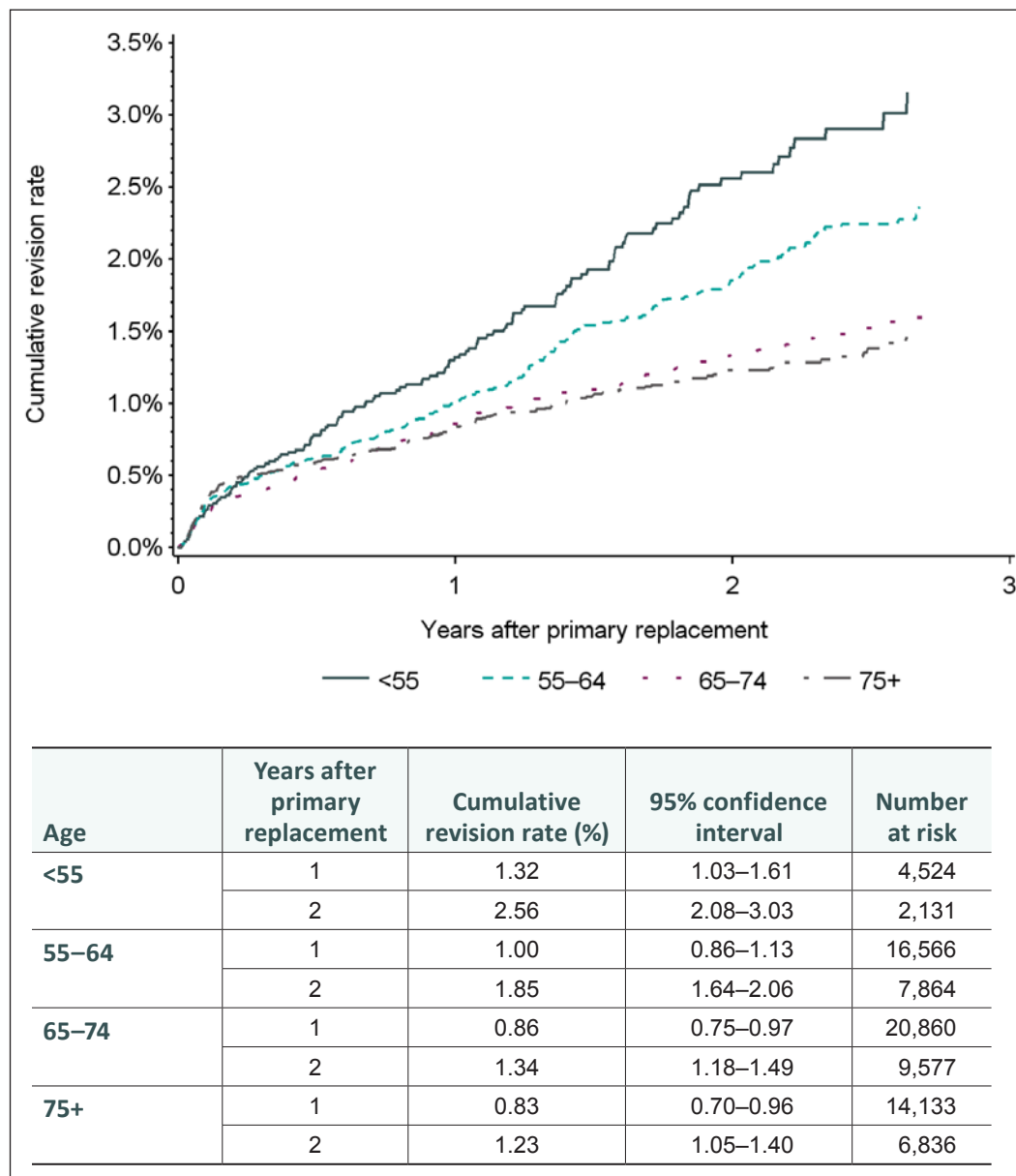
Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only), Discharge Abstract Database and National Ambulatory Care Reporting System, 2012–2013 to 2014–2015, Canadian Institute for Health Information.

**Figure 6** Cumulative revision rate for primary total knee replacement by sex (primary diagnosis of degenerative arthritis), 2012 to 2014



**Sources**  
Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only), Discharge Abstract Database and National Ambulatory Care Reporting System, 2012–2013 to 2014–2015, Canadian Institute for Health Information.

**Figure 7** Cumulative revision rate for primary total knee replacement by age group (primary diagnosis of degenerative arthritis), 2012 to 2014



#### Sources

Canadian Joint Replacement Registry (Ontario, Manitoba and British Columbia only), Discharge Abstract Database and National Ambulatory Care Reporting System, 2012–2013 to 2014–2015, Canadian Institute for Health Information.

## Revision risk: Discussion

One of the key adverse outcomes of a joint replacement is the need for an early revision surgery. Revisions are more complex than primary surgeries and have a number of implications for both the patient and the health care system, such as reduced function,<sup>4, 5</sup> longer patient recovery time<sup>4, 5</sup> and higher procedure costs.<sup>6</sup>

The revision risk curve analyses presented in this report provide a high-level view of the revision risk over the first 3 years for selected factors using the most comprehensive data source in Canada on joint replacements. Analyzing the time to revision can help identify implant, surgical and patient characteristics associated with early revisions, which can lead to more informed and appropriate decisions for patient care. While we found that early revision rates are relatively low, it is expected that over time, a person's risk of having a revision surgery increases. A systematic review published in 2011, including reports from several national registries, reported that revision rates for total hip and knee replacements could be as high as 12% after 10 years.<sup>10</sup>

Despite following patients for a period of only 3 years maximum, the results presented here are still useful to inform future national clinical practices for this defined population. It should be noted that the findings from this report are consistent with those from other national joint replacement registries.<sup>1–3</sup> Findings from the registries influence and shape best clinical practices for joint replacement patients.

The analyses in this report identify primary replacements from only 3 provinces (Ontario, Manitoba and British Columbia) due to their mandatory reporting to CJRR. Mandatory reporting across all jurisdictions will increase the value of this type of reporting and its impact on patients and the system.

One of the limitations of these analyses is that the hospital administrative data sources used can identify only deaths that occurred in an acute care setting in Canada. This limitation would potentially influence the results for the oldest age group.

## Future directions

The CJRR program at CIHI continues to expand and evolve with the intent to improve quality and outcome reporting for patients who have undergone hip or knee replacement surgeries in Canada.

### **We are continuing efforts to reach our goal of greater than 90% coverage across Canada.**

- In recent years, CJRR coverage has increased dramatically — from 42% in 2011–2012 to 71% in 2014–2015 — but even greater coverage will increase the value of this reporting and thus yield more benefit for patients and the health care systems.
- Work is under way to integrate CJRR data in the DAD, thereby leveraging an existing pan-Canadian platform to collect medical device prosthesis information. CJRR data will be accepted in the DAD as of April 1, 2018.
- With increased coverage across Canada, we will be able to provide more comprehensive analyses that include prosthesis-related outcome information to support device surveillance and monitoring, as well as to inform procurement.

### **CJRR is also currently assessing implant-specific reporting and continues to work on expanding access to product libraries that contain component characteristics and manufacturer-related information of implants used in Canadian patients.**

- For the first time, CJRR is reporting implant characteristics obtained through an international product library maintained by the International Consortium of Orthopaedic Registries (ICOR) network.
- ICOR collaborates with more than 70 stakeholders and over 30 international orthopedic registries for total hip and knee replacement representing 14 nations. This group is focused on 2 important goals: major demonstration projects of research and surveillance for hip and knee implants, and the creation of a standardized implant library, which all registries could use for consistent reporting and enhanced inter-registry collaboration.<sup>11</sup>

### **Finally, CIHI is continuing to work with health system leaders across Canada to advance a common approach for patient-reported outcome measures (PROMs) data collection and reporting.**

- As part of this program, CIHI is working in collaboration with clinical and health system management leaders and others to develop and promote a pan-Canadian approach to hip and knee replacement PROMs data collection and reporting. A PROMs Hip and Knee Working Group has been established, and work is under way toward standardized PROMs data collection to inform and improve health care delivery for hip and knee replacement patients.

# Appendix 1: CJRR coverage for 2014–2015

CJRR coverage estimates are compared with those from the Hospital Morbidity Database (HMDB) and National Ambulatory Care Reporting System (NACRS) for 2013–2014 and 2014–2015.

Note the following considerations:

- CJRR data is based on date of surgery, whereas HMDB and NACRS data is based on discharge date. However, for comparative purposes, the impact is estimated to be minimal.
- CJRR accepts data from any participating facility, including ambulatory and privately funded institutions. The HMDB reports on procedures from public acute care facilities only.

For more information, please see *Data Quality Documentation for Users: Canadian Joint Replacement Registry, 2014–2015* on CJRR's web page, at [www.cihi.ca/cjrr](http://www.cihi.ca/cjrr).

**Table A1** Hip and knee replacement coverage in CJRR, compared with HMDB and NACRS, by jurisdiction of treatment

Jurisdiction	Number of procedures submitted to CJRR in 2014–2015	Number of procedures expected in CJRR* in 2014–2015	2013–2014 coverage	2014–2015 coverage
Newfoundland and Labrador	283	1,815	8.8%	15.6%
Prince Edward Island	0	625	0.0%	0.0%
Nova Scotia	2,180	3,757	56.7%	58.0%
New Brunswick	1,986	2,785	57.7%	71.3%
Quebec	5,123	21,435	23.9%	23.9%
Ontario <sup>†</sup>	44,977	47,564	92.5%	94.6%
Manitoba <sup>†</sup>	4,170	4,241	96.6%	98.3%
Saskatchewan	4,267	5,049	58.6%	84.5%
Alberta	3,874	11,916	21.6%	32.5%
British Columbia <sup>†</sup>	14,317	14,869	94.9%	96.3%
Territories <sup>‡</sup>	0	87	0%	0%
Canada	81,177	114,143	66.6%	71.1%

## Notes

\* Sourced from the HMDB and NACRS (for knee replacements), reporting number of hospitalizations/discharges rather than procedures. Hospitalizations for bilateral procedures were counted as 2 separate procedures to be consistent with CJRR.

† As of 2012–2013, British Columbia and Ontario mandated CJRR data submission. Manitoba mandated CJRR submission as of 2013–2014.

‡ Territories include Yukon and the Northwest Territories.

Numbers are based on the province/territory in which the joint replacement was performed.

## Sources

Hospital Morbidity Database, National Ambulatory Care Reporting System and Canadian Joint Replacement Registry, 2013–2014 and 2014–2015, Canadian Institute for Health Information.



# Appendix 2: Methodological notes for revision risk curves

## Study population

Primary hip and knee replacement surgeries (total or partial) performed in provinces that have mandatory submission to the Canadian Joint Replacement Registry, followed up to a maximum of 3 years.

## Data sources

- **Primary replacements:** Canadian Joint Replacement Registry, 2012–2013 to 2014–2015; British Columbia, Manitoba and Ontario only.
- **Revision surgeries:** Discharge Abstract Database and National Ambulatory Care Reporting System, 2012–2013 to 2014–2015.
- The first occurrence of a revision surgery was identified by linkage to the primary surgery using encrypted health care number and the jurisdiction issuing the health care number, as well as a match for joint type (hip or knee) and replacement side (left or right). As such, surgeries with an invalid health care number or surgery side were excluded from the analysis.

## Methodology

- Kaplan–Meier survival analysis

## Unit of analysis

- 1 hip or knee joint replacement surgery

## Study outcome

- Time from the primary replacement to the first revision for a revised joint event. For censored surgeries, time from primary replacement to in-hospital death or the end of study period (March 31, 2015) was used.<sup>vi</sup>
- Unadjusted cumulative revision rate at 1 and 2 years, presented with 95% confidence interval (95% CI) at each year.<sup>vii</sup> Number of cases at risk is also reported for 1 and 2 years post-primary surgery.

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<sup>vi.</sup> In-hospital death was identified using the DAD or NACRS. Patients who died during the primary replacement surgery were excluded from analysis.

<sup>vii.</sup> The probabilistic complement of the Kaplan–Meier survivorship function at a given time point, multiplied by 100.

## Between-group comparisons

**Table A2** Between-group comparisons for hip revision risk (figures 1 to 4)

Group	Cohort	Categories
<b>Age (at the time of primary replacement, in years)</b>	Most responsible diagnosis: degenerative arthritis only	Younger than 55; 55 to 64; 65 to 74; 75 and older
<b>Sex</b>	Most responsible diagnosis: degenerative arthritis only	Male; female
<b>Type of procedure</b>	Most responsible diagnosis: hip fracture only	Total hip replacement; monopolar partial hip replacement; bipolar partial hip replacement
<b>Femoral fixation method*</b>	Most responsible diagnosis: hip fracture only; partial hip replacements only	Cemented fixation; cementless fixation

**Note**

\* To obtain cement fixation information for femoral stems, implant product numbers submitted to CJRR for the study population were linked to the International Consortium of Orthopaedic Registries–International Society of Arthroplasty Registries (ICOR-ISAR) Global Arthroplasty Product Library.<sup>9</sup>

**Table A3** Between-group comparisons for knee revision risk (figures 5 to 7)

Group	Cohort	Categories
<b>Type of procedure</b>	Any most responsible diagnosis	Total knee replacement; partial knee replacements (medial, lateral, patellofemoral)
<b>Age (at the time of primary replacement, in years)</b>	Most responsible diagnosis: degenerative arthritis only	Younger than 55; 55 to 64; 65 to 74; 75 and older
<b>Sex</b>	Most responsible diagnosis: degenerative arthritis only	Male; female

## Limitations

- The revision surgery could have been performed in any Canadian province or territory; however, each jurisdiction manages its own health care number, so any patient movements may result in slight under-reporting.
- This analysis assumes that the survivorship of a replacement on one side is independent from the other side, even if performed in the same patient.
- Bilateral replacement patients are double-counted because different implant prostheses may be used for each side.
- Re-revisions are not included, even though patients may have more than one revision on the same side.
- Only in-hospital deaths could be identified using the data sources for this analysis. As a result, the true probability of revision may be over-estimated.<sup>1</sup> In the future, alternative statistical methods accounting for competing risks will be explored. Kaplan–Meier confidence intervals are less reliable when the numbers at risk are small. One should not rely on them for making inferences about the differences between groups.<sup>12</sup>

## Appendix 3: Glossary

### **acetabulum**

The acetabulum is the cup-shaped socket of the hip joint. In Latin, the word “acetabulum” means cup, specifically a vinegar cup. The acetabulum is a feature of the pelvis. The head (upper end) of the femur (the thigh bone) fits into the acetabulum and articulates with it, forming a ball-and-socket joint.

### **age-standardized rate**

Age standardization is a common analytical technique used to compare rates over time, since it takes into account changes in age structure across populations and time.

### **aseptic loosening**

Aseptic loosening is the loosening of the total joint without involvement of bacteria.

### **cumulative revision rate**

Cumulative rate of revision, also known as a joint replacement failure rate, is calculated as the probabilistic complement of the Kaplan–Meier survivorship function at the given time point, multiplied by 100. This estimates the percentage of replacements revised up until that time point (e.g., 2 years), accounting for right censoring due to death, loss to follow up and the end of the most recent fiscal data year.

## **degenerative arthritis**

Degenerative arthritis refers to deterioration of the articular cartilage that lines a joint, which results in narrowing of the joint space and pain; it is also referred to as osteoarthritis.

## **fixation method**

As hip and knee joint prostheses are replaced, they are fixed securely into position in the joint. The 3 major categories of fixation methods are *cemented*, where components involved (femoral and acetabular for hip; femoral, tibial and patellar for knee) are fixed by bone cement; *cementless*, where initial fixation is achieved through a press-fit, followed by bone ingrowth for long-term stability; and *hybrid*, where one component is cemented and the other is not.

## **hip replacement**

This surgery is performed to replace all or part of the hip joint with an artificial implant. The hip is essentially a ball-and-socket joint, linking the ball at the head of the thigh bone (femur) with the cup-shaped socket in the pelvic bone. A hip prosthesis is surgically implanted to replace the damaged bone within the hip joint.

## **knee replacement**

Knee joint replacement is surgery to replace a painful damaged or diseased knee joint with an artificial joint. The orthopedic surgeon makes a cut over the affected knee. The patella (kneecap) is moved out of the way, and the ends of the femur (thigh bone) and tibia (shin bone) are cut to fit the prosthesis. Similarly, the under-surface of the patella cap is often cut to allow for placement of an artificial component.

## **median**

The median is a measure of central tendency — the middle of a distribution. The median is less sensitive to extreme scores than the mean, which makes it a better measure for highly skewed distributions.

## **partial hip replacement (also known as hemiarthroplasty)**

This surgical procedure replaces half of the hip joint with an artificial surface and leaves the other part in its natural (pre-operative) state. This usually refers to replacing the femoral head.

## **primary replacement**

A primary replacement is the first replacement procedure, where the natural bone is replaced with an artificial joint prosthesis.

## revision

Revisions are modifications to or replacements of an existing artificial hip or knee joint prosthesis/component. A revision procedure may be necessary when an existing old or worn-out hip or knee component needs to be removed and replaced with a new or improved prosthesis. This may include removing 1 or more hip or knee components as necessary.

## survival curve (or revision risk curve)

A plot of the proportion of subjects who have not yet experienced a defined event such as death or revision of prosthesis, versus time. It is also known as the cumulative percent revision (CPR). The Kaplan–Meier estimator is the one most commonly used method to calculate the survival curve. The curve takes account of subjects whose ultimate survival time is not known, a phenomenon called “censoring.”

# Appendix 4: Text alternative for figures

## Figure 1: Cumulative revision rate for primary total hip replacement by sex (primary diagnosis of degenerative arthritis), 2012 to 2014

The cumulative revision rate for each sex is plotted as a separate curve. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percentage and ranges from 0.0% to 3.5%. The 2 curves have a very similar shape: a steep increase, to over 1%, quite close to the baseline (year 0). After that, the increase is quite flat. None of the curves reach the 3-year mark. The table below the figure includes the related statistics.

## Figure 2: Cumulative revision rate for primary total hip replacement by age group (primary diagnosis of degenerative arthritis), 2012 to 2014

The cumulative revision rate for each age group is plotted as a separate curve. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percent and ranges from 0.0% to 3.5%. 3 out of the 4 curves (age groups younger than 55, 55 to 64 and 65 to 74) have a very similar shape: a steep increase, to about 1%, quite close to the baseline (year 0). The curve for age 75 and older is considerably higher than the other 3, with a more profound steep increase, to about 1.5%. After that, the increase is quite flat for the 4 curves. Just after 2-year mark, the 75 and older curve becomes closer to the other 3, although it never overlaps. None of the curves reach the 3-year mark. The table below the figure includes the related statistics.

**Figure 3: Cumulative revision rate for primary hip replacement by type of procedure (primary diagnosis of acute hip fracture), 2012 to 2014**

The cumulative revision rate for each diagnosis group (total, monopolar and bipolar partials) is plotted as a separate curve. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percent and ranges from 0.0% to 5.0%. All 3 curves, up to about 1 year, look very similar, almost as 1 curve: a steep increase, to about 2%, quite close to the baseline (year 0). At around the 1-year mark, all 3 curves separate slightly but meet each other again around year 2. None of the curves reach much further than the 2-year mark. The table below the figure includes the related statistics.

**Figure 4: Cumulative revision rate for primary partial hip replacement by femoral fixation (primary diagnosis of acute hip fracture), 2012 to 2014**

The cumulative revision rate for each of the 2 femoral fixation approaches, cemented and cementless, is plotted as a separate curve. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percent and ranges from 0.0% to 4.5%. The curves for the cementless femoral fixation are much higher and increase in a steeper manner shortly after the baseline (year 0). The curve for cemented femoral fixation is remarkably lower, and although it shows a sharp increase at the beginning, it stays below the other curve, diverging from it over time. None of the curves reach much further than the 2-year mark. The table below the figure includes the related statistics.

**Figure 5: Cumulative revision rate for primary total and partial knee replacement by type of procedure (all diagnoses), 2012 to 2014**

The cumulative revision rates for 3 partial knee types (medial, lateral and patellofemoral) are plotted together with the total knee, as 4 separate curves. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percent and ranges from 0.0% to 10%. The total knee replacement curve is the lowest, and the 3 types of partial replacement curves are the highest around the 2-year mark. None of the curves reach the 3-year mark. The table below the figure includes the related statistics.

**Figure 6: Cumulative revision rate for primary total knee replacement by sex (primary diagnosis of degenerative arthritis), 2012 to 2014**

The cumulative revision rate for each sex is plotted as a separate curve. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percent and ranges from 0.0% to 3.5%. The 2 curves have a very similar shape but diverge right at the baseline (year 0). The increase is steady over time, and the gap is increasing between them as well. None of the curves reach the 3-year mark. The table below the figure includes the related statistics.

**Figure 7: Cumulative revision rate for primary total knee replacement by age group (primary diagnosis of degenerative arthritis), 2012 to 2014**

The cumulative revision rate for each age group is plotted as a separate curve. The x-axis represents the number of years after primary replacement and ranges from 0 to 3 years. The y-axis represents the cumulative revision rate in percent and ranges from 0.0% to 3.5%. The 4 curves have a very similar shape, although they diverge shortly after the baseline (year 0). The increase is steady over time, and the gap is increasing among the 4. The highest curve is for the age group younger than 55, the one in the middle is for the age group 55 to 64. The curves for the 2 remaining groups are below and almost overlap. None of the curves reach the 3-year mark. The table below the figure includes the related statistics.

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