July 2013

Analysis in Brief

The Effect of Bearing Surface on Early Revisions Following Total Hip Arthroplasty

Key Findings

- Based on an analysis of eight years of data from the Canadian Joint Replacement Registry (CJRR), the **most common types of bearing surfaces for primary total hip arthroplasties (THAs) were metal-on-polyethylene (73%)**, followed by metal-on-metal (9%), ceramic-on-ceramic (8%) and ceramic-on-polyethylene (5%).
- Results from this analysis of Canadian osteoarthritic patients who required THAs indicate that **large-diameter modular metal-on-metal THAs had a higher cumulative revision rate at five years (5.9%)** than did metal-on-cross-linked-polyethylene THAs (2.7%).
- Factors such as **bearing surface type**, **patient age**, **geographic region of surgery** and presence of **comorbid conditions** at the time of the primary procedure were **associated with early revisions for THA** (within five years of primary THA) ($p<0.05$).
- After taking into account factors such as age, sex, geographic region, fiscal year of primary procedure and comorbid conditions, patients who underwent a **large-diameter modular metal-on-metal THA were 1.6 times more likely to have a revision within five years than patients with a metal-on-cross-linked-polyethylene THA**.

Introduction

Total hip arthroplasty (THA) is one of the most commonly performed surgical procedures to restore function and quality of life for patients with degenerative arthritis of the hip; it has been described as “the operation of the 20th century.”[1, 2] In Canada, more than 40,000 THAs are performed annually, and this number has increased over the past decade.[3]

A key measure of success for THAs is how long patients benefit from their procedure before needing a revision surgery. Revisions are more complex than primary THAs and have a number of implications for both the patient and the health care system, including longer lengths of stay,[4] longer patient

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recovery time[5–7] and higher procedure costs[8] than for primary THAs.[i] 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 the Canadian Joint Replacement Registry (CJRR) at the Canadian Institute for Health Information (CIHI). Characteristics of the implant, surgeon and patient all influence the long-term outcomes of THAs. The choice of materials used for the bearing surface of the implant is an important decision that is determined by the orthopedic surgeon and that can influence revision rates.

Historically, THA bearing surfaces have consisted of a metal femoral head combined with a polyethylene acetabular cup; however, in some cases, breakdown of the polyethylene has been found to occur over time, contributing to the degeneration of bone and loosening of the implant (osteolysis and aseptic loosening).[9] To address this issue of wear debris, alternatives to traditional metal-on-polyethylene have been developed. These alternatives include using other bearing surfaces (such as ceramic-on-ceramic and metal-on-metal), modifying the polyethylene through cross-linking (cross-linked polyethylene) and using ceramic heads to interface with the polyethylene cup.

Many factors influence a surgeon's choice of bearing surface for a particular patient, including patient characteristics (such as age, activity level, health and bone stock), familiarity with a particular implant or bearing surface, implant availability, implant femoral head size required and product performance.[10–13]

Studies conducted in other countries to investigate the relative outcomes of THA using different bearing surfaces typically use revision surgery within a period of 5 to 10 years from the primary surgery as an outcome.[14–16] A few Canadian studies have reported outcomes following metal-on-metal THA in recent years, with varying results.[17–19] However, this present study is, to our knowledge, the largest Canadian study to investigate revision rates of THA based on different bearing surface types. Using data from CJRR and CIHI's acute care hospitalization database, the Discharge Abstract Database (DAD), this Canadian study investigates the impact of bearing surface materials and other factors such as age, sex and comorbidities at the time of the primary procedure on the occurrence of revisions within five years of the primary THA.

Total Hip Arthroplasty: A Clinical Overview

A total hip arthroplasty (or total hip replacement) involves replacing the diseased or damaged hip joint with an artificial joint. The implanted joint consists of a ball component (metal or ceramic) that replaces the femoral head, and a socket component (metal cup that may include a polyethylene, ceramic or metal insert or liner) that replaces the acetabulum. Surgeons select the materials used in the ball and socket articulation, also called the bearing surface, after giving careful consideration to many factors, including the patient's age, sex and level of physical activity, and the surgeon's own preference. The most common bearing surface group in modern total hip replacements is metal-on-polyethylene, which indicates a metal femoral head articulating against a polyethylene acetabular insert (refer to Appendix A for more details).

A failed THA is marked by the need for a subsequent surgery to revise the original implant. Reasons for revision may include infection of the joint and mechanical complications of the implant. Revisions have implications for patient outcomes and costs.

i. Lengths of stay are, on average, 7 hospital days for patients undergoing a revision versus 6 for a primary THA.[4] Patient recovery time can take weeks to months, with patients experiencing significant limitations in their mobility, productivity and independence.[5–7] Hospital-related expenditures for a typical hip revision procedure in Canada (one not involving infection) are estimated at $12,802, whereas expenditures for a primary (unilateral) THA procedure are estimated to be $8,855.[8] Note that these are not full costs, as they do not include other expenditures such as physician payments and rehabilitation.

The Canadian Joint Replacement Registry: An Introduction

The Canadian Joint Replacement Registry is a pan-Canadian information system for hip and knee replacements that records and analyzes the level of activity, clinical parameters and outcomes of primary and revision hip and knee replacements over time. One of the primary goals of CJRR is to reduce overall revision rates for hip and knee replacements.

This study is based on 56,942 THAs for which data was voluntarily submitted to CJRR from British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, New Brunswick, Nova Scotia, Newfoundland and Labrador and the Northwest Territories. Quebec elected to not participate in this study.

During the study period (2003–2004 to 2010–2011), CJRR coverage of THAs performed in Canada ranged from 37% to 41%, excluding Quebec. Beginning in 2012–2013, Ontario and B.C. mandated reporting to CJRR. Manitoba mandated submission to CJRR beginning in 2013–2014.

Methodology

Study Cohort and Revision Procedures

A cohort of 72,331 patients[ii] who underwent a primary THA between 2003–2004 and 2010–2011 was identified in CJRR. To ensure a more homogeneous sample, the cohort was limited to patients diagnosed with degenerative osteoarthritis, as reported in CJRR (n = 61,768, representing 85% of the initial cohort).

As revision procedures were to be obtained from the DAD, each CJRR procedure record was associated with its corresponding primary record in the DAD to ensure proper calculation of revision rates. With a linkage rate of 92%, the final study cohort contained 56,942 patients.

A second linkage was performed to determine whether each patient in the study cohort underwent a revision procedure (captured in the DAD) within five years of the primary surgery. A total of 1,438 first-revision procedures were identified (subsequent revisions, if any, were ignored for the purposes of this study). Appendix B provides more information regarding the linkage methodology as well as the Canadian Classification of Health Interventions (CCI) codes that reflect primary THA and revision procedures.

Statistical Analysis

Patients were grouped by their age into 10-year intervals, with the exception of patients younger than 55 and older than 75; these patients were grouped more broadly because of small sample sizes. The Charlson comorbidity index (a measure of the burden of comorbid disease status) at the time of the primary THA was calculated on the basis of coding algorithms for defining comorbidities in ICD-10.[20, 21] Using this index, patients were categorized into two groups: those without a comorbid condition (index value equals 0) and those with at least one comorbid condition (index value greater than 0). The jurisdictions where each primary procedure was performed were grouped into three geographic regions: Northern and Western (B.C., Alberta, Saskatchewan and the Northwest Territories), Central (Manitoba and Ontario) and Eastern (New Brunswick, Nova Scotia and Newfoundland and Labrador). Statistical Analysis Software (SAS) v9.2 (North Carolina, U.S.) was used for all linkages and analyses, and the level of significance was set at 0.05 for all statistical tests.

The chi-square statistical test was used to test the distribution of categorical variables such as age group and sex across bearing surface groups in this study.

ii. For the purpose of this report, we use the term “patients” rather than procedures, acknowledging that it is possible for the same patient to undergo a primary THA on each side of the body.

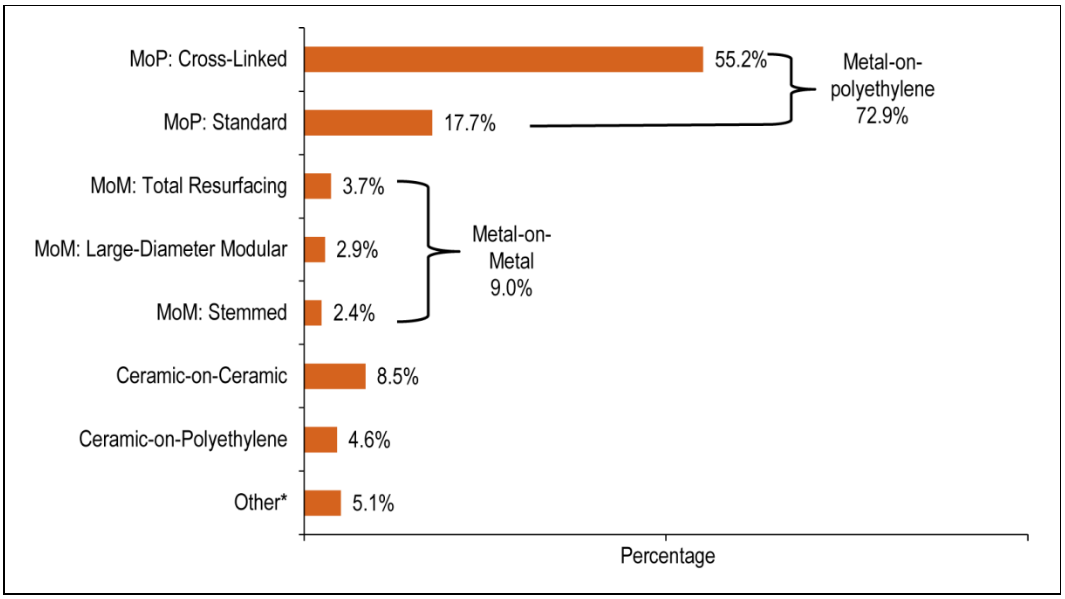
Kaplan–Meier curves were used to estimate the cumulative revision rate by type of bearing surface for the cohort over five years of observation. Patients were followed for up to five years from the date of the primary procedure. A revision that occurred within five years of the primary procedure was considered an early revision event. Patients were censored (removed from the analysis) if they experienced more than five years of observation or reached the end date of observation without a revision (March 31, 2012, for this study).

Hazard ratios with 95% confidence intervals from a Cox proportional hazard model were used to assess and adjust for risk factors for revision, including age, sex, fiscal year of primary procedure, geographic region where the primary procedure was performed and the patient's Charlson comorbidity index value.

Results

The distribution of primary THAs by bearing surface group and subgroup is presented in Figure 1, and a breakdown of these numbers by fiscal year is presented in Appendix A, Table A1. During the period 2003–2004 to 2010–2011, the most common type of bearing surface material used was metal-on-polyethylene (73%), with metal-on-cross-linked-polyethylene (55%) being more common than metal-on-standard-polyethylene (18%). Metal-on-metal bearing surfaces were used in 9% of THAs, with total resurfacing being more common (4%) than either large-diameter modular metal-on-metal (3%) or stemmed metal-on-metal (2%) bearing surfaces. The number of metal-on-metal THAs increased from 2003–2004 to a peak in 2007–2008, but has since declined steadily.

Figure 1: Distribution of Total Hip Arthroplasty by Bearing Surface Group



Notes

* Other includes bearing surfaces that were reported as "other," as well as smaller groups (for example, ceramic-on-metal and metal-on-ceramic).

n = 56,942.

MoP: metal-on-polyethylene.

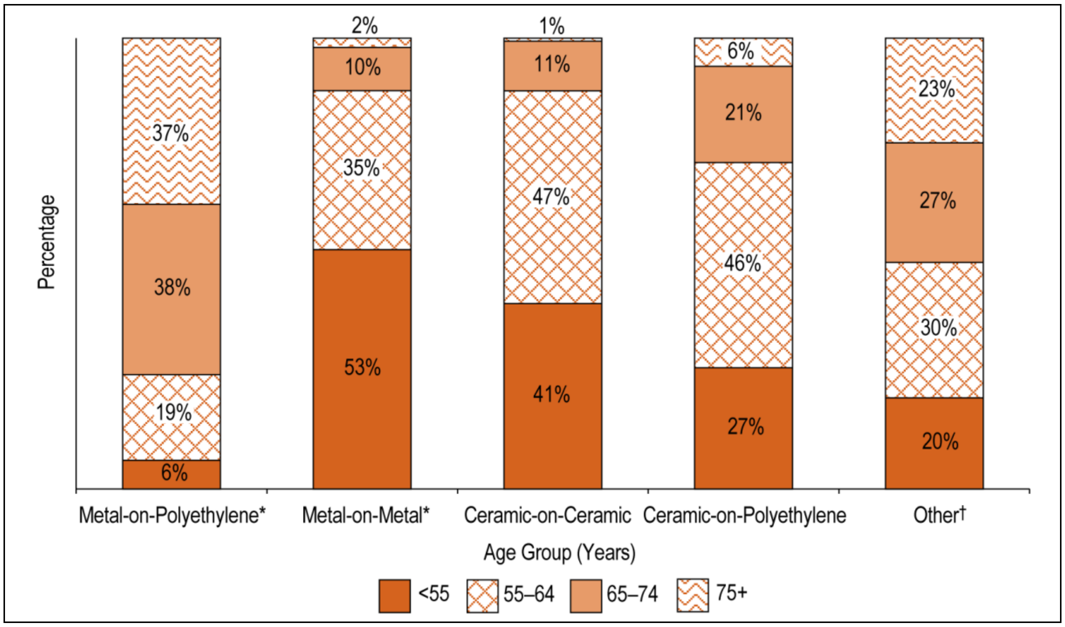
MoM: metal-on-metal.

A description of each bearing surface group can be found in Appendix A.

Sources

Canadian Joint Replacement Registry and Discharge Abstract Database, 2003–2004 to 2010–2011, Canadian Institute for Health Information.

Figure 2: Distribution of Bearing Surface Group Usage* by Patient Age Group



Notes

* Bearing surfaces were grouped into broad categories. Metal-on-metal includes total resurfacing, large-diameter modular and stemmed subgroups. Metal-on-polyethylene includes the standard and cross-linked subgroups.

† Other includes bearing surfaces that were reported as "other," as well as smaller groups (for example, ceramic-on-metal and metal-on-ceramic).

A description of each bearing surface group can be found in Appendix A.

The figure excludes 12 patients of unknown age.

Sources

Canadian Joint Replacement Registry and Discharge Abstract Database, 2003–2004 to 2010–2011, Canadian Institute for Health Information.

The distribution of primary THA procedures by both type of bearing surface and age group is presented in Figure 2. The majority of patients who received a metal-on-metal THA (88%) were younger than 65, whereas the majority of patients who received a metal-on-polyethylene THA (75%) were older than 65 ($p<0.05$). When analyzed by sex (Table 1), patients who received a metal-on-metal THA were more likely to be male than female, whereas the opposite trend was observed in nearly all other bearing surface types ($p<0.05$). For instance, 76% of metal-on-metal THA patients were male, compared with 41% in the metal-on-polyethylene group. Looking more closely at this interaction according to age group, findings indicate that metal-on-metal bearing surfaces were more prevalent among younger male patients.

Table 1: Distribution of Sex and Bearing Surface Group Usage* by Patient Age Group

	Bearing Surface Group									
	Metal-on-Polyethylene*		Metal-on-Metal*		Ceramic-on-Ceramic		Ceramic-on-Polyethylene		Other	
Age Group	Patients (N)	Males (%)	Patients (N)	Males (%)	Patients (N)	Males (%)	Patients (N)	Males (%)	Patients (N)	Males (%)
<55	2,658	51	2,725	78	1,986	49	698	43	587	36
55–64	7,866	45	1,809	76	2,278	49	1,182	42	871	42
65–74	15,682	43	492	73	532	53	554	45	768	45
75+	15,270	36	105	54	32	47	162	45	673	36
Total	**41,476**	**41**	**5,131**	**76**	**4,828**	**50**	**2,596**	**43**	**2,899**	**40**

Notes

* Bearing surfaces were grouped into broad categories. Metal-on-metal includes total resurfacing, large-diameter modular and stemmed subgroups. Metal-on-polyethylene includes the standard and cross-linked subgroups.

† Other includes bearing surfaces that were reported as "other," as well as smaller groups (for example, ceramic-on-metal and metal-on-ceramic).

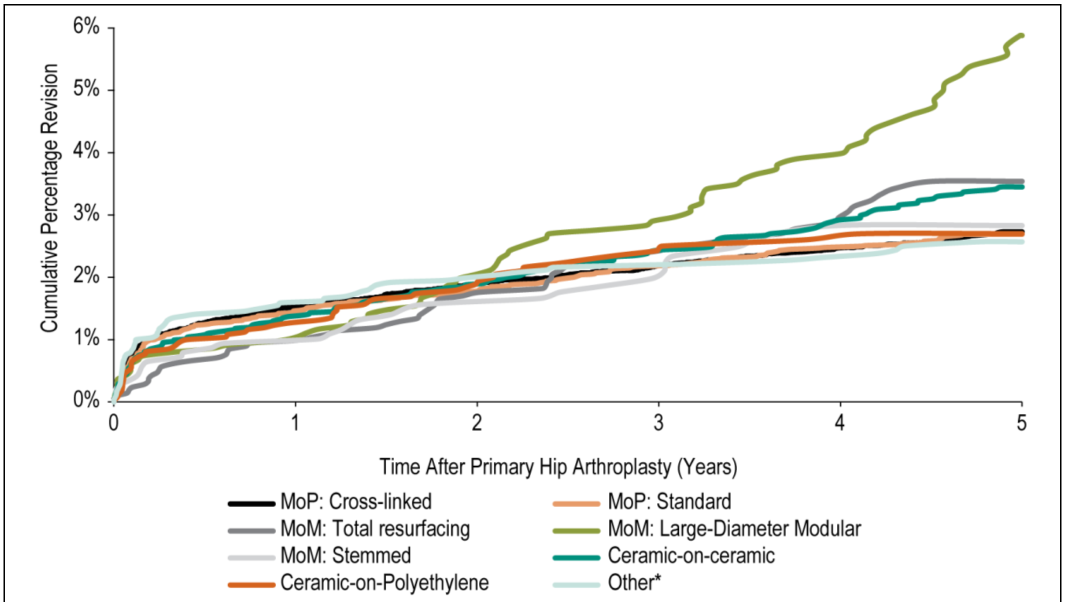
A description of each bearing surface group can be found in Appendix A.

The table excludes 12 patients of unknown age.

Sources

Canadian Joint Replacement Registry and Discharge Abstract Database, 2003–2004 to 2010–2011, Canadian Institute for Health Information.

Figure 3: Cumulative Percentage Revision by Bearing Surface Group



Bearing Surface Group	Year 1		Year 3		Year 5	
	Cumulative Percentage Revision	Cases at Risk	Cumulative Percentage Revision	Cases at Risk	Cumulative Percentage Revision	Cases at Risk
MoP: Cross-Linked	1.5	30,938	2.2	20,406	2.7	12,700
MoP: Standard	1.5	9,923	2.2	8,937	2.7	7,869
MoM: Total Resurfacing	1.0	2,099	2.4	1,495	3.5	881
MoM: LD Modular	1.0	1,613	2.9	1,386	5.9	556
MoM: Stemmed	1.0	1,370	2.1	849	2.8	512
Ceramic-on-Ceramic	1.4	4,762	2.4	3,584	3.5	2,560
Ceramic-on-Polyethylene	1.3	2,563	1.9	1,334	2.7	917
Other*	1.6	2,853	2.2	2,257	2.6	1,516

Notes

* Other includes bearing surfaces that were reported as “other,” as well as smaller groups (for example, ceramic-on-metal and metal-on-ceramic). A description of each bearing surface group can be found in Appendix A.

MoP: metal-on-polyethylene.

MoM: metal-on-metal.

LD: large-diameter.

Sources

Canadian Joint Replacement Registry and Discharge Abstract Database, 2003–2004 to 2010–2011, Canadian Institute for Health Information.

Cumulative percentage revisions within five years of primary THA for each bearing surface group were estimated using Kaplan–Meier curves (Figure 3). Results from this analysis describe how the probability of revision after primary THA changes over time. In the years following a primary THA, most bearing surfaces had similar cumulative revision rates up until the two-year mark, after which distinct patterns began to emerge. By the five-year mark, large-diameter modular metal-on-metal THA had the highest cumulative percentage revision among all groups (5.9%), which was more than double that of the most common bearing surface subgroup, metal-on-cross-linked-polyethylene (2.7%).

Table 2 shows the hazard ratios for revision within a five-year period, calculated using the Cox proportional hazards model and adjusted for covariates such as sex, age group, bearing surface group, fiscal year of primary procedure, geographic region where the primary procedure was performed and the Charlson comorbidity index value at the time of the primary procedure. Sex and fiscal year of primary THA procedure were not significant risk factors for having a revision within five years; however, patients younger than 55 were significantly more likely to have an early revision than patients between the ages of 65 and 74 (hazard ratio = 1.22, p<0.05). When looking at the effect of type of bearing surface on the risk of revision, patients who underwent a large-diameter modular metal-on-metal THA were 1.6 times more likely to have a revision within five years as patients who had a THA with the most common bearing surface, metal-on-cross-linked-polyethylene (hazard ratio = 1.61, p<0.01). Patients receiving a primary THA in the eastern regions of Canada had a higher risk of revision than those in the central regions of Canada (hazard ratio = 1.35, p<0.01). The risk of revision among patients with at least one comorbid condition was 1.5 times greater than among patients without any comorbid conditions (hazard ratio = 1.47, p<0.01).

Table 2: Cox Proportional Hazards Model for Revision Within Five Years After Total Hip Arthroplasty

Risk Factor	Hazard Ratio	95% Confidence Interval	p-Value
Sex			
Male	1.00		
Female	0.90	0.81–1.00	0.05
Age Group			
<55	1.22	1.02–1.45	0.03*
55–64	1.09	0.94–1.27	0.24
65–74	1.00		
75+	1.03	0.90–1.18	0.67
Bearing Surface Group†			
MoP: Cross-Linked	1.00		
MoP: Standard	1.02	0.88–1.19	0.79
MoM: Total Resurfacing	1.02	0.76–1.35	0.89
MoM: Large-Diameter Modular	1.61	1.23–2.07	<0.01*
MoM: Stemmed	0.89	0.61–1.27	0.55
Ceramic-on-Ceramic	1.05	0.86–1.29	0.61
Ceramic-on-Polyethylene	0.96	0.72–1.25	0.74
Other‡	0.95	0.74–1.22	0.74
Fiscal Year of Primary Procedure			
2003–2004	0.85	0.67–1.09	0.20
2004–2005	0.95	0.76–1.19	0.66
2005–2006	1.02	0.81–1.28	0.88
2006–2007	0.90	0.72–1.13	0.36
2007–2008	1.12	0.90–1.40	0.31
2008–2009	0.96	0.77–1.20	0.71
2009–2010	1.01	0.81–1.27	0.93
2010–2011	1.00		

Table 2: Cox Proportional Hazards Model for Revision Within Five Years After Total Hip Arthroplasty (cont'd)			
Risk Factor	**Hazard Ratio**	**95% Confidence Interval**	**p-Value**
Geographic Region§			
Central (Man., Ont.)	1.00		
Eastern (N.B., N.S., N.L.)	1.35	1.16–1.58	<0.01*
Northern and Western (B.C., Alta., Sask., N.W.T.)	1.02	0.90–1.15	0.8
Charlson Comorbidity Index Value			
0	1.00		
>0	1.47	1.11–1.91	<0.01*

Notes

* Statistically significant at p<0.05.

† A description of each bearing surface group can be found in Appendix A.

‡ Other includes bearing surfaces that were reported as "other," as well as smaller groups (for example, ceramic-on-metal and metal-on-ceramic).

§ Jurisdictions were combined into regional centres, as follows. Western and Northern: British Columbia, Alberta, Saskatchewan and the Northwest Territories; Central: Manitoba and Ontario; Eastern: New Brunswick, Nova Scotia and Newfoundland and Labrador. This study does not include data from Quebec, Prince Edward Island, Yukon and Nunavut.

MoP: metal-on-polyethylene.

MoM: metal-on-metal.

Sample cohort size, number of revisions and contributing person-years can be found in Appendix C.

Sources

Canadian Joint Replacement Registry and Discharge Abstract Database, 2003–2004 to 2010–2011, Canadian Institute for Health Information.

Discussion

The primary cohort used for this study (n = 56,942 patients) was identified from data voluntarily submitted to CJRR during the observation period and is one of the largest cohorts of its kind in Canada. It is important to note the study's limitations when interpreting the results:

- First, the CJRR data used in this study represents approximately 37% to 41% of THA procedures performed across Canada (excluding Quebec). This coverage reflects the voluntary nature of CJRR during the study period and also the exclusion of Quebec data, as Quebec elected to not participate in this study.
- Second, bearing surface was self-reported by the CJRR data providers during the study period; as such, there is a risk that the type of bearing surface was misclassified. To mitigate this potential data quality risk and to address recent concerns over patient safety,[22–24] the coding of metal-on-metal bearing surface groups was additionally validated by CIHI's CJRR staff.
- Finally, the loss to follow-up because of patient death or the patient moving to another jurisdiction is another potential limitation, but one that is expected to be small and have had minimal impact on the overall findings.

Despite the above-noted limitations, this study provides valuable new information on patterns of bearing surface use in Canada and their contributions to early revision rates following a primary THA. Metal-on-cross-linked-polyethylene was found to be the most common bearing surface used in THA. Use of metal-on-metal implants in Canada increased to a peak in 2007–2008. This is likely because of potential improvements in metal-on-metal implant design and concerns about polyethylene debris generated by some metal-on-polyethylene designs. However, since that time, the use of metal-on-metal bearing surface for THAs has declined. This study found that most bearing surfaces had similar cumulative revision rates up until the two-year mark following primary THA. Additional analyses indicated that revisions within one year were primarily attributable to issues not related to the mechanics of the implant but rather to medical complications, such as infection, traumatic injury and arthrosis (data not shown). Divergent patterns of cumulative revision rates began to appear after the two-year mark, with patients who underwent large-diameter modular metal-on-metal THA demonstrating the highest cumulative revision rate compared with other groups. By the five-year mark, large-diameter modular metal-on-metal THA had the highest cumulative revision rate among all groups (5.9%), which was more than double the rate of metal-on-cross-linked-polyethylene (2.7%), the most common bearing surface subgroup.

As described in the introduction, results from several other studies have associated certain THA bearing surfaces with increased risk of revision. A 10-year follow-up study conducted by Milosev et al. found that metal-on-metal bearings had higher revision rates than ceramic-on-ceramic bearings; however, neither the metal-on-metal nor the ceramic-on-ceramic bearings demonstrated significantly different mid-term results compared with conventional metal-on-polyethylene bearings.[25] In other studies examining metal-on-metal bearing surfaces, Smith et al. reported that metal-on-metal THAs tracked by the National Joint Registry of England and Wales had significantly higher five-year revision rates than either ceramic-on-ceramic or metal-on-polyethylene THAs, and that the revision rates were also related to large femoral head size.[14] Bolland et al. also reported high revision rates (cumulative revision rate of 7.6% at five years) with large-diameter metal-on-metal THA.[26] Comparisons between types of polyethylene have also been addressed in THA studies. Engh et al. reported that THA with cross-linked polyethylene had a lower revision rate 10 years after the primary procedure when compared with non-cross-linked-polyethylene THA.[27] This suggests that factors other than bearing surface types can contribute to a patient's risk of revision.

In this CJRR study, large-diameter metal-on-metal THAs had a higher cumulative percentage revision within five years of the primary THA (5.9%) than either metal-on-metal stemmed (2.8%) or metal-on-metal total resurfacing (3.5%) procedures. Metallic orthopedic implants generate metal debris from wear and corrosion over time that is detectable in the blood, tissue and urine,[28] and studies have shown that an increased femoral head size in metal-on-metal implants may affect the circulating metal ion level.[29] Increased levels of metal ions in the urinary and circulatory systems in some cases may be indicative of complications from the joint implant.[30, 31] A randomized clinical trial conducted by a Canadian team reported that patients who received a large-head metal-on-metal THA had a median 46-fold increase in serum cobalt levels over baseline and that median serum chromium increased 10-fold one year after the THA.[32] However, a biological reaction to metal debris may take several years to develop,[11] and the toxic-effects threshold for circulating metal ions has yet to be determined.[33] This underscores the importance of adequate follow-up to ensure appropriate studies of implant performance.

Data from other joint replacement registries has shown that the method of fixation (cemented or cementless) may be a potential confounder for the risk of revision for THAs. Results from both the Australian Orthopaedic Association National Joint Replacement Registry and the National Joint Registry of England and Wales demonstrated higher revision rates with cementless than with cemented implants.[15, 16] Fixation methods of the stem and cup were investigated as a risk factor for early revision in this analysis; however, we found that surgeon-reported fixation method was not a statistically significant risk factor for revision within the five-year follow-up period (data not shown).

This study also included an investigation of risk factors for early revision of a primary THA and confirmed previous findings that the presence of comorbid conditions during the primary procedure is a significant risk factor for revision.[34–36] In addition, results indicate that patients younger than 55 had a higher risk of revision within five years of a THA, which may suggest that higher activity levels after the primary procedure may contribute to early revision, as similarly reported by Le Duff et al.[37] Overall, the findings observed in this CJRR study are consistent with those found in the literature and by other international registries, including the Australian Orthopaedic Association National Joint Replacement Registry[16] and the National Joint Registry of England and Wales.[15] However, differences in cohort size, length of follow-up period and bearing surface categorizations need to be taken into consideration, and caution should be used when making any direct comparisons.

In summary, the revision rate within five years of a primary THA varied among bearing surface groups. Cumulative revision rates were highest for large-diameter modular metal-on-metal THAs (5.9%), in comparison to the most common bearing surface group, metal-on-cross-linked-polyethylene (2.7%). In addition to bearing surface types, patient age and sex, geographic region and fiscal year of primary procedure, and the presence of comorbid conditions at the time of the primary procedure were all significantly associated with an increased risk of revision. Next steps for CJRR analyses may include using manufacturer-reported descriptions rather than surgeon-reported data categories to verify all bearing surface groups, controlling for fixation methods and examining the effect of head size on the risk of early revision. As more jurisdictions mandate submission to CJRR, increased coverage will improve statistical power and the representativeness of revision studies of the Canadian joint replacement population.

Acknowledgements

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Appendix A: Bearing Surface Groupings

Primary total hip replacements were grouped into the following bearing surface categories:

Metal-on-Polyethylene

- **Cross-linked:** A metal femoral head articulates against a cross-linked polyethylene acetabular insert/liner in an acetabular cup.
- **Standard:** A metal femoral head articulates against a standard polyethylene acetabular insert/liner in an acetabular cup.

Metal-on-Metal

- **Total resurfacing:** A bone stock–preserving procedure leaves much of the patient's femoral head intact, using instead a metal cap-like resurfacing head that articulates against a metal acetabular cup without an acetabular insert/liner.
- **Large-diameter modular:** A large-diameter (typically >36 mm) metal femoral head articulates against a metal acetabular cup without an acetabular insert/liner.
- **Stemmed:** A metal femoral head articulates against a metal acetabular insert/liner in an acetabular cup.

Ceramic-on-Ceramic

- A ceramic femoral head articulates against a ceramic acetabular insert/liner in an acetabular cup.

Ceramic-on-Polyethylene

- A ceramic head articulates against a polyethylene acetabular insert/liner in an acetabular cup.

Other

- Procedures for which either one or both of the articulating surface materials were marked as "other," as well as bearing surface combinations not detailed above, such as ceramic-on-metal and metal-on-ceramic, were grouped as "other."

Table A1: Type of Total Hip Arthroplasty in the Study Cohort by Fiscal Year

Bearing Surface Group		Fiscal Year								Overall
		2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	
MoP	**Cross-Linked**	2,435	3,519	3,062	3,570	3,769	4,437	5,249	5,377	**31,418**
	Standard	2,464	2,719	1,492	1,116	778	535	468	498	**10,070**
	Subtotal	**4,899**	**6,238**	**4,554**	**4,686**	**4,547**	**4,972**	**5,717**	**5,875**	**41,488**
MoM	**Total Resurfacing**	82	234	195	212	406	405	323	262	**2,119**
	LD Modular	5	24	87	465	491	347	146	64	**1,629**
	Stemmed	40	75	99	126	184	328	285	246	**1,383**
	Subtotal	**127**	**334**	**381**	**803**	**1,082**	**1,080**	**755**	**573**	**5,135**
Ceramic-on-Ceramic		450	810	741	584	483	584	544	632	**4,828**
Ceramic-on-Polyethylene		89	150	201	290	251	383	569	663	**2,596**
Other		476	659	159	204	251	372	362	416	**2,899**
	Total	**6,041**	**8,190**	**6,036**	**6,567**	**6,613**	**7,391**	**7,946**	**8,158**	**56,942**

Notes

MoP: metal-on-polyethylene.

MoM: metal-on-metal.

LD: large-diameter.

Source

Canadian Joint Replacement Registry, 2003–2004 to 2010–2011, Canadian Institute for Health Information.

Appendix B: CJRR and DAD Linkage Methodology and CCI Codes for Revision

- Primary procedures in CJRR were linked to primary procedures in the DAD using unique patient identifiers (health care authority code and encrypted provincial/territorial health care number) and a common data element of surgery date that had less than three days' difference between the two databases. In total, 72,331 procedures were linked between the DAD and CJRR using this method.
- Hip revision procedures were identified by linking the study cohort of primary THAs to hip revision procedures (attribute status of *revision* and CCI code 1.VA.53 *implantation of internal device, hip joint* or 1.SQ.53 *implantation of internal device, pelvis*). Revision procedures were linked between the DAD and CJRR using health care authority code, encrypted provincial/territorial health care number and the same side of joint as primary procedure. Hospitalizations before the date of primary THA were excluded. The first revision after the primary procedure was used to determine the revision rate within five years.

Appendix C: Cox Proportional Hazard Cohort Details

Table C1: Number of Procedures, Revisions and Corresponding Person-Years Used in the Cox Proportional Hazard Model

Bearing Surface Group*	k	N	Person-Year†
MoP: Cross-Linked	743	31,412	137,162
MoP: Standard	260	10,063	63,022
MoM: Total Resurfacing	60	2,119	9,112
MoM: Large-Diameter Modular	75	1,629	7,045
MoM: Stemmed	31	1,383	5,176
Ceramic-on-Ceramic	142	4,828	23,845
Ceramic-on-Polyethylene	59	2,596	9,414
Other‡	69	2,899	14,710

Notes

* A description of each bearing surface group can be found in Appendix A.

† Person-year was used to take into account varying lengths of observation periods among patients.

‡ Other includes bearing surfaces that were reported as “other,” as well as smaller groups (for example, ceramic-on-metal and metal-on-ceramic).

MoP: metal-on-polyethylene.

MoM: metal-on-metal.

k: the number of revision procedures.

N: the study cohort population size.

The table excludes 13 patients of unknown age and gender.

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