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Cost-Utility of Metal-on-Metal Hip Resurfacing Compared to Conventional Total Hip Replacement in Young Active Patients with Osteoarthritis

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ABSTRACT

Background: Metal-on-metal hip resurfacing arthroplasty (MoM HRA) has emerged as an alternative to total hip arthroplasty (THA) for younger active patients with osteoarthritis (OA). Birmingham hip resurfacing is the most common MoM HRA in Alberta, and is therefore compared with conventional THA. **Objective:** The objective of this study was to estimate the expected cost-utility of MoM HRA versus THA, in younger patients with OA, using a decision analytic model with a 15-year time horizon. **Methods:** A probabilistic Markov decision analytic model was constructed to estimate the expected cost per quality-adjusted life-year (QALY) of MoM HRA versus THA from a health care payer perspective. The base case considered patients with OA aged 50 years; men comprised 65.9% of the cohort. Sensitivity analyses evaluated cohort age, utility values, failure probabilities, and treatment costs. Data were derived from the Hip Improvement Project and the Hip and Knee Replacement Pilot databases in Alberta, the 2010 National Joint Replacement Registry of the Australian Orthopaedic Association, and the literature. **Results:** In the base case, THA was dominated by MoM HRA (incremental mean costs of –$583 and incremental mean QALYs of 0.079). In subgroup analyses, THA remained dominated when cohort age was 40 years instead of 50 years or when only men were assessed. THA dominated when the cohort age was 60 years or when only women were assessed. Results were sensitive to utilities, surgery costs, and MoM HRA revision and conversion probabilities. At a willingness-to-pay of Can $50,000/QALY, there was a 58% probability that MoM HRA is cost-effective. **Conclusions:** The results show that, on average, MoM HRA was preferred to THA for younger and male patients, but THA is still a reasonable option if the patient or clinician prefers given the small absolute differences between the options and the confidence ellipses around the cost-effectiveness estimates.

Keywords: Birmingham, cost-utility, hip resurfacing, osteoarthritis, total hip replacement.

Introduction

Advanced hip osteoarthritis (OA) is a common chronic condition causing severe joint pain and loss of joint function. Its incidence and prevalence are rising as the population ages, and OA now affects an estimated 10% of Canadian adults [1]. Total hip arthroplasty (THA) is recognized as one of the most effective interventions to relieve pain and improve function for patients with severe OA [2,3]. Although many different prostheses are available, they generally consist of three parts: the acetabular component, which is fitted into the patient's native acetabular pelvic bone; the femoral component, which is inserted down the femoral canal; and the bearing surfaces [4].

Revision surgery is required in about 10% of the patients with THA [5,6]. THA revision is more difficult to perform than is primary THA, and clinical outcomes are often poorer [7]. Therefore, people expected to outlive a primary THA are typically considered for THA only when their symptoms become unmanageable by nonsurgical treatment.

Other surgical approaches, such as hip resurfacing arthroplasty (HRA), have been considered. HRA is bone conserving because the head of the femur is not completely removed, although damaged surfaces of the proximal femur and the acetabulum are removed.

The first HRA developed in the early 1950s was abandoned because of high failure rates [5,6,8,9], and early results in the 1970s and 1980s with the first metal-on-metal (MoM) bearings were disappointing because of excessive wear, osteolysis, bone loss, and early failure of the prostheses leading to revision surgery [5,6,8,9]. Recent bearing material improvements have made HRA a viable option once again, particularly in younger and more active patients or those ineligible for THA. Nonetheless, the safety of MoM HRA remains controversial, with complications including femoral neck fractures, component loosening, and metallosis [5,6,8,9]. Despite these concerns and limited evidence regarding revision surgery, the Canadian Joint Replacement Registry reports an increasing trend in the number of MoM HRAs in Canada (<1% of all types of hip replacement in 2003 to 3% in 2007) [10].

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Potential advantages of the MoM HRA over THA include minimum bone resection, conservation of femoral bone, and maintenance of normal femoral loading and stress [6,7]. Hence, MoM HRA is particularly suitable for patients with a large femoral offset or a wide femoral canal, or those with femoral shaft deformity, in which it is difficult to fit a stem [11]. These characteristics are more common in men; consequently, an important indication for considering MoM HRA is sex.

Other than sex, age is considered to be another important criterion because implant survival of THA in younger patients is generally lower. Fifteen-year implant survival rate increases with age from approximately 70% in patients younger than 50 years to approximately 95% in patients older than 75 years at the time of primary surgery [12,13]. Most MoM HRA studies include only younger patients (~≤60 years) [6,14–18]. Nevertheless, some studies suggest that MoM HRA is also a suitable option for older patients (~≥60 years) [19–21].

To the best of our knowledge, only three randomized controlled trials (RCTs) comparing THA and MoM HRA have been published [22–24]. None of these studies compared health-related quality of life (HRQOL) and costs in age- and sex-specific subgroups. Given the lack of appropriate and high-quality data for a sufficiently long follow-up period, decision analytic modeling is a useful approach to estimate the long-term costs and HRQOL associated with MoM HRA and THA on the basis of known information regarding costs, HRQOL, and the probability of clinical outcomes such as revisions and complications [25].

The purpose of this study was to inform health policy by estimating the expected incremental cost-utility of MoM HRA to THA, for a base-case population and in age- and sex-specific subgroups. The comparison is based on current orthopaedic practice patterns in Alberta, Canada, where MoM Birmingham HRA and THA are most frequently used.

Methods

Model Structure

A probabilistic Markov state-transition model with a 15-year time horizon was developed to undertake a cost-utility analysis of primary MoM HRA compared with THA. The model was built in TreeAge Pro 2012 (TreeAge Software, Inc., Williamstown, MA) following established economic evaluation modeling guidelines [25,26]. We calculated the cost per quality-adjusted life-year (QALY) for each intervention. The analysis adopted a health care system perspective. Both costs and outcomes were discounted at 3% per annum to reflect society's rate of time preference [27–29].

The model begins with a decision for either MoM HRA or THA (Fig. 1). After the primary surgical procedure, patients enter either the postprimary MoM HRA or postprimary THA health state. Patients are always in one of a finite number of health states and can move between health states annually. One-year cycles were chosen because a revision surgery, which is one of the most important events to happen in the context of the decision model, is on average likely to occur no more frequently than once per year. Patients are at risk of death from surgery-related or other causes and therefore can always move to the absorbing death state.

Patients in the postprimary MoM HRA state can remain in that state or fail and then either have their MoM HRA revised or undergo a conversion to THA. The choice for revision or

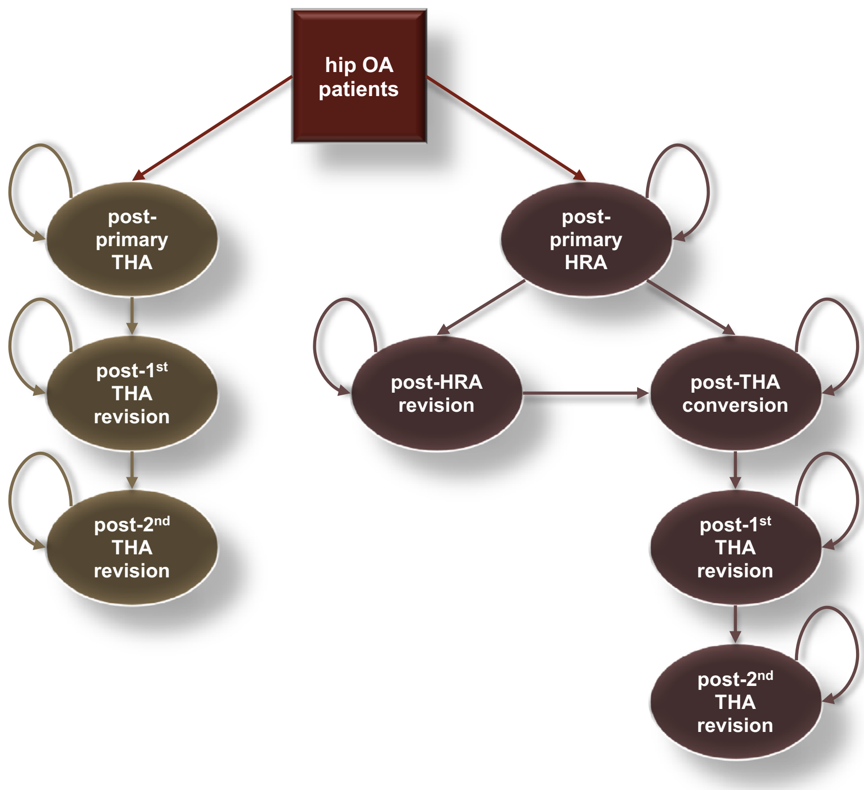

Fig. 1 – Markov model comparing MoM HRA and THA procedures. Transition to the absorbing death state is possible from every health state (not shown in the figure). Each state is a 15-year tunnel (not shown in the figure). MoM HRA, metal-on-metal hip resurfacing arthroplasty; THA, total hip arthroplasty.

conversion is based on patient condition and patient and surgeon preference. Converted THAs can be revised twice. Similarly, patients with THA may undergo revision twice. Given that only approximately 0.8% of Canadian patients require more than two revisions, the model did not include third revisions [10]. Because the revision probability is dependent on the time since surgery, tunnel states allowed for different transition probabilities given time since primary surgery.

At each cycle, patients incur health care costs and have a utility applied dependent on the health state they are in. Transitions are associated with a one-time cost associated with surgery and a health utility decrement associated with device failure. In addition, a proportion of patients undergoing surgery experience a major complication not requiring surgery, but results in increased health costs and a reduced utility. A half-cycle correction was applied.

Data Sources (Table 1)

The model was mainly populated with estimates derived from the Hip Improvement Project (HIP) [30] and the Hip and Knee Replacement Pilot (HKRP) project [31]. Both studies were managed by the Alberta Bone & Joint Health Institute. A systematic review was performed to confirm and supplement input variables.

HIP Study [30]

HIP began enrolling patients in 2004, with 1340 patients consenting. HIP was designed to provide evidence for orthopaedic surgeons and decision makers in Alberta regarding orthopaedic devices for younger patients with OA. Eligible patients were those undergoing either MoM HRA or THA for advanced hip OA, aged 18 years or older and 65 years or younger for men and 55 years or younger for women. Birmingham HRA is the device used in patients undergoing MoM HRA.

The HKRP Study [31]

The HKRP RCT randomized patients with OA in Alberta requiring hip or knee replacement to either a new care pathway or the existing standard of care [31]. Pain, function and HRQOL outcomes, and costs were compared over 12 months postsurgery.

Probabilities

Revision is defined as the replacement or extraction of one, several, or all prosthesis parts [12,32]. Since the revision probability is dependent on the time since surgery, tunnel states allowed for different transition probabilities given time since surgery. An overview of the transition probabilities in the first cycle postsurgery and their data sources is presented in Table 1. The National Joint Replacement Registry of the Australian Orthopaedic Association (AOA) was used to obtain procedure-, age-, and sex-specific cumulative percentages of patients who underwent revision surgery for the period between 1999 and 2009 [33], as the model time horizon exceeds the follow-up time for HIP. The AOA was chosen because it had a large sample size (n = 184,629) and reported separate data for first and second THA revisions and MoM HRA revisions and conversions from HRA to THA. The AOA reported on revision probabilities for different THA-bearing surfaces. Weighted average probabilities representing the proportions of bearing surfaces used in HIP were calculated.

The transition probability was highest in the year postsurgery and declined thereafter. This is due to the higher chance that the prosthesis failed in the first year after surgery.

Surgical mortality was applied as a 90-day postsurgical mortality in any cycle in which a surgery occurred. We assumed background mortality for the remainder of that cycle and in all other cycles (i.e., cycles in which no surgery was performed). In the first year postsurgery, mortality was calculated as (0.25 × postsurgical mortality) + (0.75 × general mortality). Ninety-day postprimary surgical mortality was used to represent the first quarter of the year (i.e., 0.25) and was derived from the Swedish Registry and assumed to be similar for primary MoM HRA and THA because there is neither evidence nor the expectation that postprimary mortality differs between the two procedures [12]. Postrevision mortality was not available in the Swedish Registry. Evidence indicates that postsurgical mortality is higher for revisions and conversions. Therefore, we scaled the postprimary mortality values by a ratio of postprimary to postrevision surgical mortality [39].

Annual sex- and age-specific all-cause mortality rates were based on Alberta life tables [34].

Major complications following surgery not requiring revision were obtained from HIP (Table 1). Complications included all-cause adverse events related to the procedure: pulmonary embolism, myocardial infarction, deep venous thrombosis, infection, dislocation, unexpected pain, and fracture. Minor complications were not included in the model, yet assumed to be similar for subgroups.

Health-State Utilities

Short-form 36 health survey scores from HIP were converted to a six-dimensional health state short form (derived from the SF-36) (SF-6D) preference-based summary score [40–42] to inform our primary surgery utilities. These were calculated for age groups 55 years and younger and older than 55 years, based on AOA age groups. Because the mean baseline utility scores differed in the MoM HRA and THA groups (0.608 and 0.570, respectively), we adjusted THA utilities by the ratio of the MoM HRA and the THA baseline scores for sex and age subgroups, assuming independence of outcome and baseline score. The utility for the first cycle was calculated as a weighted average from scores 3 and 12 months postsurgery (Table 1). The utility pattern was assumed to remain stable 2 years postsurgery. This value is the average of scores at 2 and 3 years postsurgery.

Postrevision utilities were not available. A ratio of postrevision to post–primary surgery calculated from two studies that used the EuroQol five-dimensional questionnaire [35,36] was applied to our primary surgery utilities to estimate postrevision values. Because of a lack of literature for an alternative assumption, utilities after a conversion to THA were assumed to be similar to utilities after a first revision for THA.

To approximate the utility of people experiencing a serious complication not requiring surgery, we applied the ratio of the utility following medical complications relative to the utility following successful surgery, as taken from Gu et al. [37]. We assumed that a major complication reduced utility for 3 months regardless of surgery type.

Utility decrements represent the temporary lower health state of a patient in the period before surgery, when patients have increased pain and decreased mobility. We assumed that patients experienced this decrement for 5 weeks, based on the average wait time for revision in Alberta. To approximate the utility of people awaiting a revision or conversion, we applied a ratio of presurgical revision THA to presurgical primary THA calculated from Ostendorf et al. [35] and Dawson et al. [36]. This ratio was applied to the presurgical utility values from HIP.

Costs

Where available, costs in the model were based on actual costs in HIP and HKRP patients. Costs are from the health care system perspective.

Table 1 – Base-case variable values used in cost-effectiveness analysis.

Variable	Value (SD)		Distribution		Source
	MoM HRA	THA	MoM HRA	THA	
Transition probabilities					
Postprimary MoM HRA to:[*]					
MoM HRA revision	0.00889 (0.00108)	NA	Dirichlet (67, 39, 7436)	NA	[33]
THA conversion	0.00515 (0.0082)				
Postprimary THA or post-THA conversion to first THA revision[*]	0.01365 (0.00046)	0.01365 (0.00046)	Beta (872, 63062)	Beta (872, 63062)	[33]
Following first HRA revision to THA conversion[*,†]	0.02128 (0.00909)	NA	Beta (5, 246)	NA	[33]
Following first THA revision to second THA revision[*,†]	0.07968 (0.00531)	0.07968 (0.00531)	Beta (207, 2391)	Beta (207, 2391)	[33]
Death due to surgery[*,†,‡]	0.00760 (0.00036)	0.00760 (0.00036)	Beta (431, 56331)	Beta (431, 56331)	[12]
Age- and sex-specific general mortality for Alberta[*]	0.00320	0.00320	None	None	[34]
Probability of major complication[†]	0.01217 (0.00494)	0.01205 (0.00691)	Beta (6, 487)	Beta (3, 246)	HIP
Utilities					
Primary surgery					
Cycle 1	0.799 (0.114)	0.795 (0.125)	Gamma	Gamma	
Cycle ≥2	0.818 (0.104)	0.810 (0.113)	Gamma	Gamma	HIP
Complication	0.667 (0.115)	0.663 (0.125)	Gamma	Gamma	
Revision and conversion surgery					
Cycle 1	0.661 (0.114)	0.658 (0.125)	Gamma	Gamma	
Cycle ≥2	0.676 (0.104)	0.669 (0.113)	Gamma	Gamma	HIP [35–37]
Complication	0.551 (0.115)	0.548 (0.125)	Gamma	Gamma	
Revision failure[†]	0.590 (0.103)	0.553 (0.113)	Gamma	Gamma	HIP [37]
Proportion of cycle revision failure applied[†]	0.096 (0.0–1.0)	0.096 (0.0–1.0)	Triangular (0, 0.096, 1)	Triangular (0, 0.096, 1)	Internal data
Proportion of cycle complication utility applied[†]	0.25 (0.0–0.5)	0.25 (0.0–0.5)	Triangular (0, 0.25, 0.5)	Triangular (0, 0.25, 0.5)	Assumption
Costs ($)					
Primary surgery	14,746 (2,503)	14,717 (6,180)	Gamma	Gamma	HIP, ASCM
Revision and conversion surgery	21,960 (2,466)	21,916 (6,912)	Gamma	Gamma	HIP, ASCM, [38]
Year postsurgery	1,019 (543)	1,171 (838)	Gamma	Gamma	HIP
Major complication[†]	7,034 (4,618)	7,034 (4,618)	Gamma	Gamma	HKRP

Note. Values are generally age- and sex-specific, except where noted. ASCM, Alberta standard costing model; HIP, Hip Improvement Project; HKRP, Hip and Knee Replacement Pilot; MoM HRA, metal-on-metal hip resurfacing arthroplasty; NA, not applicable; THA, total hip arthroplasty.

[*] First-year value presented; transition probabilities change with each year postsurgery.

[†] Age- and sex-specific values not available (i.e., value does not change in subgroup analyses).

[‡] Death due to surgery occurs only on entering a health state.

[¶] Range of values is shown in parentheses in lieu of SD.

Regional health authorities provided prosthesis costs, and Alberta Health and Wellness (AHW) provided physician costs. Through chart review, we collected the number of perioperative, allogeneic, and autologous blood units transfused, type and amount of cement used, surgery length, and the number of nurses and assistants attending the surgery. Unit costs for blood transfusion were from two Canadian studies [43,44], and cement unit costs were from the HKRP. Data from the Alberta Standard Costing Model (internal data) were used to estimate other surgical (e.g., nursing) and direct per diem hospitalization costs. Indirect hospitalization costs were provided by Alberta Health Services. The Alberta Standard Costing Model was a case-costing project undertaken to provide region-specific costs for THA and total knee replacement, including surgery and follow-up care.

To estimate revision costs, we applied a ratio of primary to revision surgery from a Canadian source [38]. We assumed that THA conversion costs were similar to THA revision costs.

Costs for the year postsurgery included costs for orthopaedic surgeon visits, physiotherapy, clinic, and prescription analgesics covered by the AHW. Orthopaedic surgeon visits were extracted

Table 2 – Probabilistic base-case results and sensitivity analyses.

Comparator	Costs ($)	QALYs	Incremental		ICER
			Costs ($)	QALYs	
Base case					
Men and women 50 y*					
MoM HRA	17,884	12.089			THA dominated
THA	18,467	12.010	583	−0.079	
Sex					
Men, age = 50 y*					
MoM HRA	17,202	12.161			THA dominated
THA	18,057	11.906	856	−0.255	
Women, age = 50 y*					
THA	18,960	12.037			HRA dominated
MoM HRA	19,706	11.879	746	−0.158	
Age (y)					
40*					
MoM HRA	18,072	12.368			THA dominated
THA	18,961	12.236	889	−0.132	
60*					
THA	17,465	11.659			HRA dominated
MoM HRA	17,527	11.377	61	−0.282	
Sex and age					
Men, age = 40 y*					
MoM HRA	17,390	12.502			THA dominated
THA	18,681	11.831	1,291	−0.670	
Women, age = 40 y*					
MoM HRA	19,368	12.062			
THA	19,591	12.326	223	0.264	$846
Men, age = 60 y*					
MoM HRA	16,651	11.243			
THA	17,507	11.774	856	0.531	$1,613
Sensitivity analyses					
Men, age = 50 y*					
Utility = non–age-/–sex-specific					
MoM HRA	17,185	12.077			THA dominated
THA	18,110	11.969	925	−0.108	
Women, age = 50 y*					
Utility = non–age-/–sex-specific					
THA	18,937	12.127			HRA dominated
MoM HRA	19,710	12.125	772	−0.002	
Age = 40 y*					
Utility = non–age-/–sex-specific					
MoM HRA	18,071	12.372			THA dominated
THA	18,972	12.292	901	−0.080	
Age = 60 y*					
Utility = non–age-/–sex-specific					
THA	17,459	11.293			
MoM HRA	17,507	11.373	48	0.080	$600

HRA, hip resurfacing arthroplasty; MoM HRA, metal-on-metal hip resurfacing arthroplasty; THA, total hip arthroplasty; ICER, incremental cost-effectiveness analysis; QALY, quality-adjusted life-year.

* Age of the cohort in cycle 1.

from the AHW claims database, and Alberta Health Services provided clinic costs, including overhead. Patients provided physiotherapy and prescription analgesic utilization, as well as their insurance status. We obtained the unit costs from AHW formularies to calculate the cost. We assumed that the year postrevision or postconversion costs were the same as year post–primary surgery costs.

Because of incomplete physician resource data, we included only orthopaedic visit costs. As reported in the literature, MoM HRA is equivalent to THA regarding the required staff [6]. Therefore, we expected the costs for other specialties to be similar for MoM HRA and THA.

We assumed that complication costs were the same regardless of surgery type. Complication costs included treatment and hospitalization costs. Because of the small number of patients with complications, it was not possible to calculate reliable subgroup costs.

All costs were inflated to 2011 Canadian dollars by using annual health care Consumer Price Index [45].

Base-Case and Subgroup Probabilistic Sensitivity Analyses

Cumulative expected QALYs and costs were calculated for both MoM HRA and THA, and probabilistic sensitivity analyses (PSAs) were performed for both the base case and age- and sex-specific subgroups. For PSAs, the method-of-moments approach was used for parameter estimation of the probability distribution. Method-of-moments fitting involves equating the mean and standard error as observed from the underlying data set to the expressions for the mean and standard error of the appropriate distribution, for example, a Dirichlet or beta distribution for transition probabilities, and gamma distributions for utilities and costs. The parameters of that distribution (α,β) can then be solved analytically [46].

The base-case cohort consisted of patients enrolled in HIP who had baseline data (presurgery), hospital chart review data, and a minimum of 1-year follow-up.

The base case considered patients with OA aged 50 years with a men-to-women ratio identical to that in the HIP cohort of younger than 55 years (men = 65.9%). Age 50 years is near the average age in the HIP study (MoM HRA = 49.7 years; THA = 49.6 years). Because age and sex are both associated with implant survival, ICERs may differ between specific age and sex subgroups, which could potentially lead to different recommendations for these subgroups. To explore this, model outcomes were analyzed for seven age- or-sex-specific subgroups: men only ($\leq$65 years), women only ($\leq$55 years), men and women aged 40 years, men and women aged 60 years, men-only aged 40 years, women-only aged 40 years, and men-only aged 60 years.

A priori, we planned for a subgroup analysis on 55-year-old women, but the number of valid observations was insufficient.

Second-order uncertainty was estimated via Monte Carlo sampling. In each of 10,000 iterations, a random sample of parameter values was drawn from its corresponding distribution (Table 1). The mean joint estimate of the incremental costs and QALYs was derived from the incremental cost and QALY estimates produced by the PSA. Where both the mean incremental costs and QALYs were positive, the ICER was calculated. In addition, scatterplots and cost-effectiveness acceptability curves were generated to illustrate the uncertainty.

PSAs of Utility

Uncertainty around the utility values was addressed through PSAs. We reran the subgroup analyses by using the base-case utility values in lieu of age- and sex-specific utilities (see Appendix 1 in Supplemental Materials found at http://dx.doi.org/10.1016/j.jval.2013.06.021).

Deterministic Threshold Analyses

The degree of influence of surgery costs, complication costs, revision, and conversion and complication probabilities for the MoM HRA strategy on the outcome of the cost-effectiveness analysis was examined by using single parameter threshold analyses, by changing the value for each parameter until one of the strategies became dominated (i.e., ceteris paribus).

Results

Base-case and Subgroup Analyses

MoM HRA dominated THA in the base case (mean difference in costs is −$583 and mean difference in QALYs is 0.079). The dominated strategy is the one with higher costs and fewer QALYs. The nondominated strategy is the one with lower costs and more QALYs. Patients with MoM HRA are expected to experience higher lifetime QALYs and have lower health care costs compared with patients with THA.

The cost-utility of MoM HRA compared with that of THA varied by sex and age (Table 2). In PSAs, THA remained dominated when primary surgery was performed at 40 years rather than 50 years (mean difference in costs is −$889 and mean difference in QALYs is 0.132) and when 50-year-old men (mean difference in costs is −$856 and mean difference in QALYs is 0.255) or 40-year-old men (mean difference in costs is −$1291 and mean difference in QALYs is 0.670) were assessed; from an allocative efficiency viewpoint, MoM HRA is to be preferred in these subgroups. MoM HRA was dominated when the primary surgery was performed at 60 years (mean difference in costs is $61 and mean difference in QALYs is − 0.282) rather than 50 years and when only 50-year-old women were assessed (mean difference in costs is $746 and mean difference in QALYs is −0.158). The ICERs for 60-year-old men and 40-year-old women was $1613 and $846, respectively.

The 95% confidence intervals around the scatterplot estimates are wide and overlapping all four quadrants in the cost-effectiveness plane for the base case and all subgroups (Fig. 2).

Figure 3 demonstrates the uncertainty around which intervention is cost-effective at different decision thresholds. In the base case, a willingness-to-pay value of $50,000/QALY [47,48] resulted in a 58% probability that MoM HRA is cost-effective compared with THA (Fig. 3A). This probability does not change at $100,000/QALY. In 50-year-old men, the probability that MoM HRA is cost-effective is higher—72% (Fig. 3B). In 50-year-old women, however, the probability that THA is cost-effective versus MoM HRA is always higher (Fig. 3C). This probability peaks at 67% for a willingness-to-pay value of $5,000/QALY. At $50,000/QALY, the probability that THA is cost-effective in 50-year-old women is 64%.

PSAs of Utility

In the subgroup analyses, we used age- and sex-specific utilities (see Appendix 1 in Supplemental Materials found at http://dx.doi.org/10.1016/j.jval.2013.06.021). To assess the sensitivity of the results to the utility inputs, the subgroup analyses were rerun by using utilities that were not age- and sex-specific (i.e., average utility for all patients with MoM HRA or THA) (Table 2). THA remained dominated in the 40-year-old and all-men cohorts. MoM HRA remained dominated for the all-women cohort. Only in the 60-year-old cohort did the results change with utilities that were not age- and sex-specific. THA now cost $600/QALY relative to MoM HRA, whereas THA was dominated by MoM HRA when we used age- and sex-specific utilities.

THA remained dominated when costs and outcomes discounting was changed from 3% to either 0% or 5% (results not shown).

Deterministic Threshold Analyses

Results were sensitive to MoM HRA revision and conversion probabilities (Fig. 4) and surgery costs. The revision/conversion probability for patients who had a primary MoM HRA surgery must increase 16% for THA to no longer be dominated by MoM HRA (i.e., ICER = $0/QALY). To put this into perspective, in the first year the combined probabilities of revision or conversion to THA must increase from 1.5% (base-case value) to 1.8%. At a 63% increase (e.g., combined probabilities in first year must increase to 2.5%), MoM HRA is dominated by THA in the base-case cohort (Fig. 4).

Threshold analyses showed that primary MoM HRA surgery cost must increase 2% of the base-case value ($14,746–$15,115) for the ICER to equal $0/QALY. MoM HRA revision surgery cost must increase to 44% of the base-case value ($21,916– $31,449) for the ICER to equal 0$/QALY.

Results were not sensitive to complication costs or complication probabilities. The base-case values of $7,034 and 1.2% must increase over 500% to either $35,221 or 6.1% for THA to appear on the cost-effectiveness frontier.

Discussion

The purpose of this study was to inform health policy by estimating the cost-utility of MoM HRA to THA, for a base-case population of patients with OA aged 50 years, and in age- and sex-specific subgroups.

The present study is the first comparison of MoM HRA and THA with sufficiently long follow-up. This study used actual cost data obtained in two cohorts (HIP and HKRP), performed probabilistic analysis, and discounted the results. This results in a more realistic estimate of the true uncertainty of the cost-effectiveness compared with deterministic analysis. The results of this study confirm results reported in other studies: MoM HRA could be cost-effective for patients younger than 65 years [4,5,22]. These results, however, should be interpreted with care. The PSA

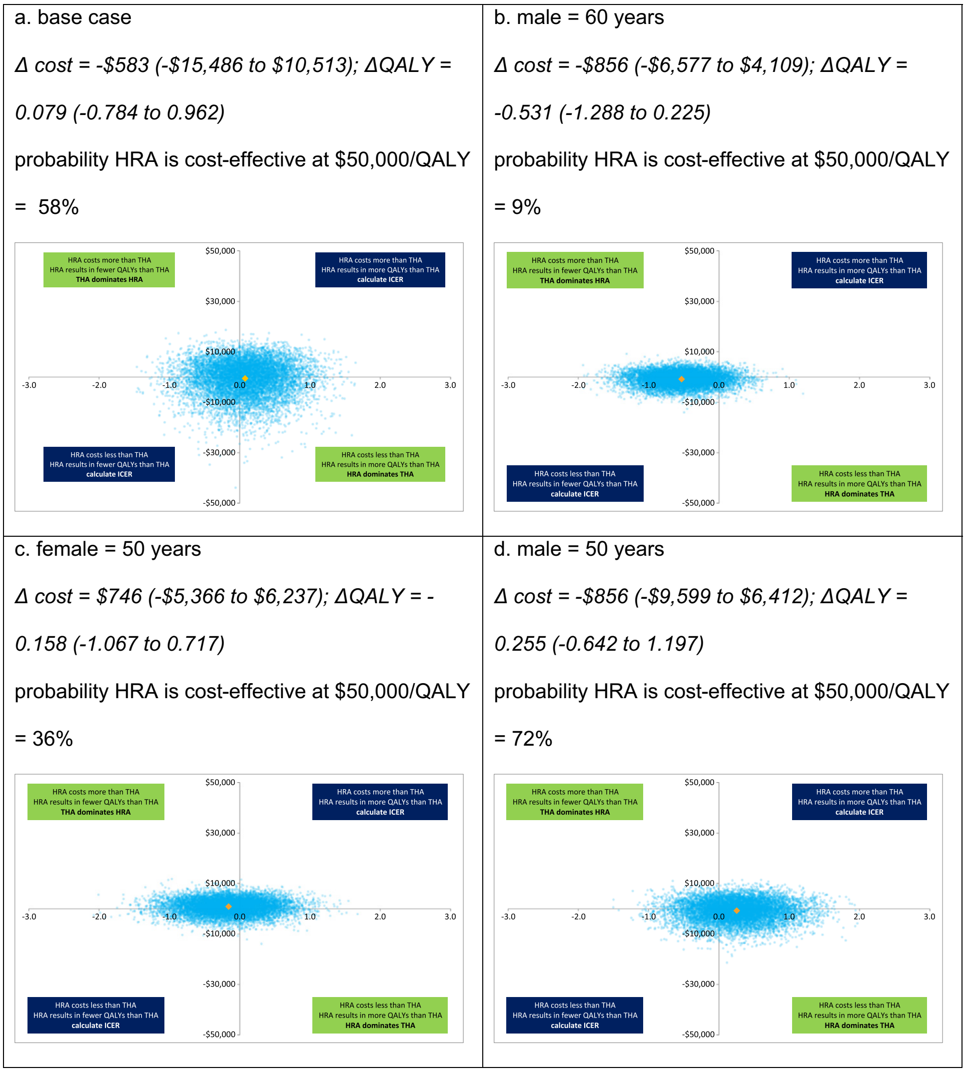

Fig. 2 – Scatterplots of incremental costs and QALYs on the cost-effectiveness plane for the base case (male and female patients with OA of the hip, aged 50 years) and subgroup analyses. THA is at the origin. The diamond near the origin represents the point estimate. ICER, incremental cost-effectiveness ratio; MoM HRA, metal-on-metal hip resurfacing arthroplasty; OA, osteoarthritis; QALY, quality-adjusted life-year; THA, total hip arthroplasty.

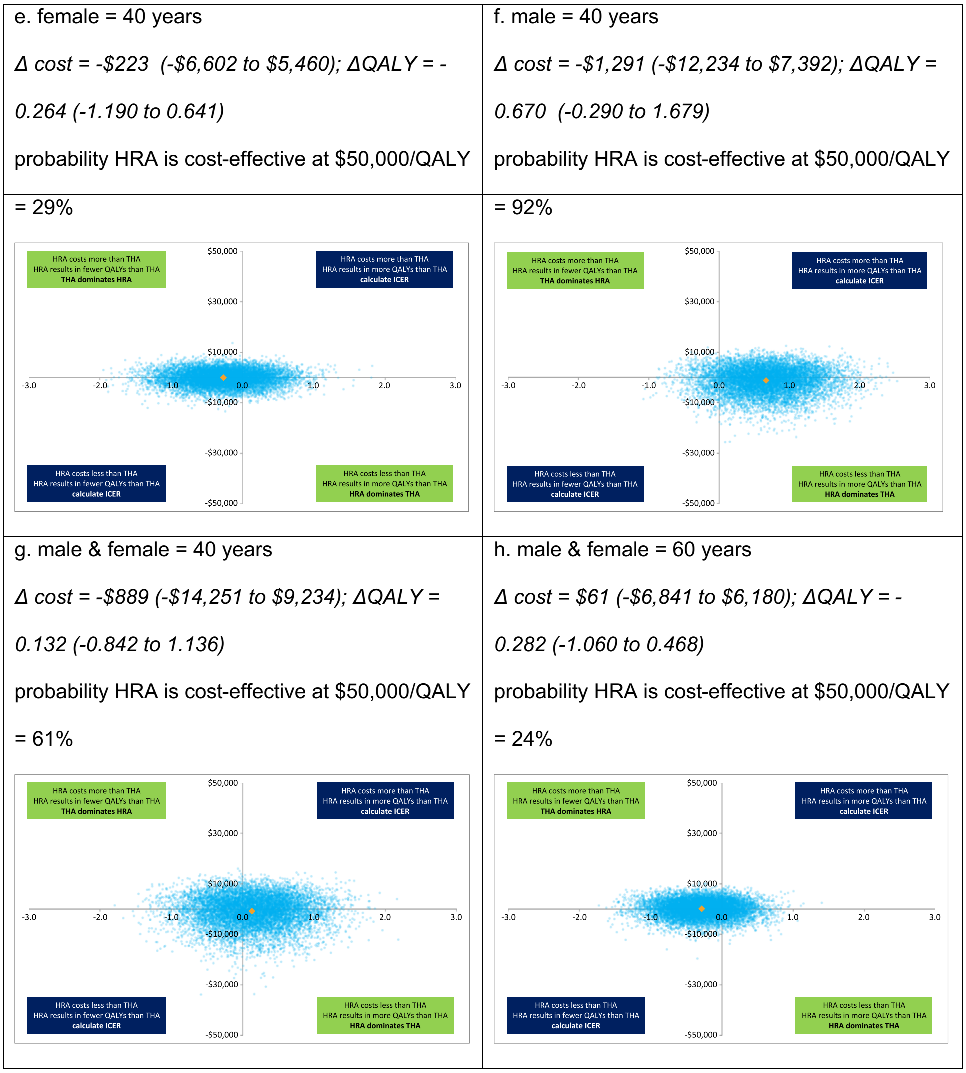

Fig. 2 – *continued*

scatterplot of the probabilistic base-case results might lead one to believe that MoM HRA is the best choice, but the 95% confidence interval around the base-case ICER is wide and overlapping all four quadrants in the cost-effectiveness plane (Fig. 2A). Furthermore, the cost-effectiveness acceptability curve shows that the probability MoM HRA is cost-effective compared with THA ranges from 50.2% to 58.6% over a range of lambdas (the maximum amount a decision maker is willing to pay per QALY) between 0 and $200,000/QALY.

The results and uncertainty in base-case analyses suggest that in terms of cost-effectiveness there is little difference between MoM HRA and THA. With surgical interventions, we expect more variation in outcomes due to factors such as clinical experience with each of the techniques. Some subgroup results indicate, however, that from an allocative efficiency viewpoint, a specific procedure is preferred. For example, HRA is very likely to generate more QALYs than THA in 40-year-old men (Fig. 2F). In contrast, MoM HRA is expected to generate fewer QALYs than THA in 60-year-old men (Fig. 2B). Although the incremental costs may be lower for MoM HRA, whether this could be considered cost-effective or acceptable in practice depends on the willingness to accept a QALY loss. In other subgroups, the fairly equal distribution of simulated model outcomes around the origin indicates that no preferred option can be distinguished on the basis of current cost-effectiveness data.

In the base case, MoM HRA dominated THA (mean difference in cost of −$583 and in QALYs of 0.079). That is, the MoM HRA strategy results in lower costs and more QALYs than does the THA strategy. The higher HRQOL in patients with MoM HRA is complementary with literature reporting better health outcomes [6,7]. Contradictory with other literature reporting on higher costs for MoM HRA [5], comparable costs for THA and MoM HRA were found in this study. Despite the higher average costs of the MoM HRA device ($7,199 vs. $5,256 in THA), the THA procedure had higher total costs. The reported lower total costs for MoM HRA were mainly explained by the lower surgery and hospitalization costs. Patients who received an MoM HRA had generally a shorter length of stay (3.3 days) than did patients who received THA (4.8 days). Another explanation of the cost difference might be the use of actual cost data from HIP and the HKRP [49]. Other comparable decision analyses studies often used reimbursement costs [5,6]. Potential advantages of MoM HRA for specific patient groups are reported in the literature [4,6,11]. This study suggests that MoM HRA was preferable in men and THA was preferable in women. Our results confirm the reported better

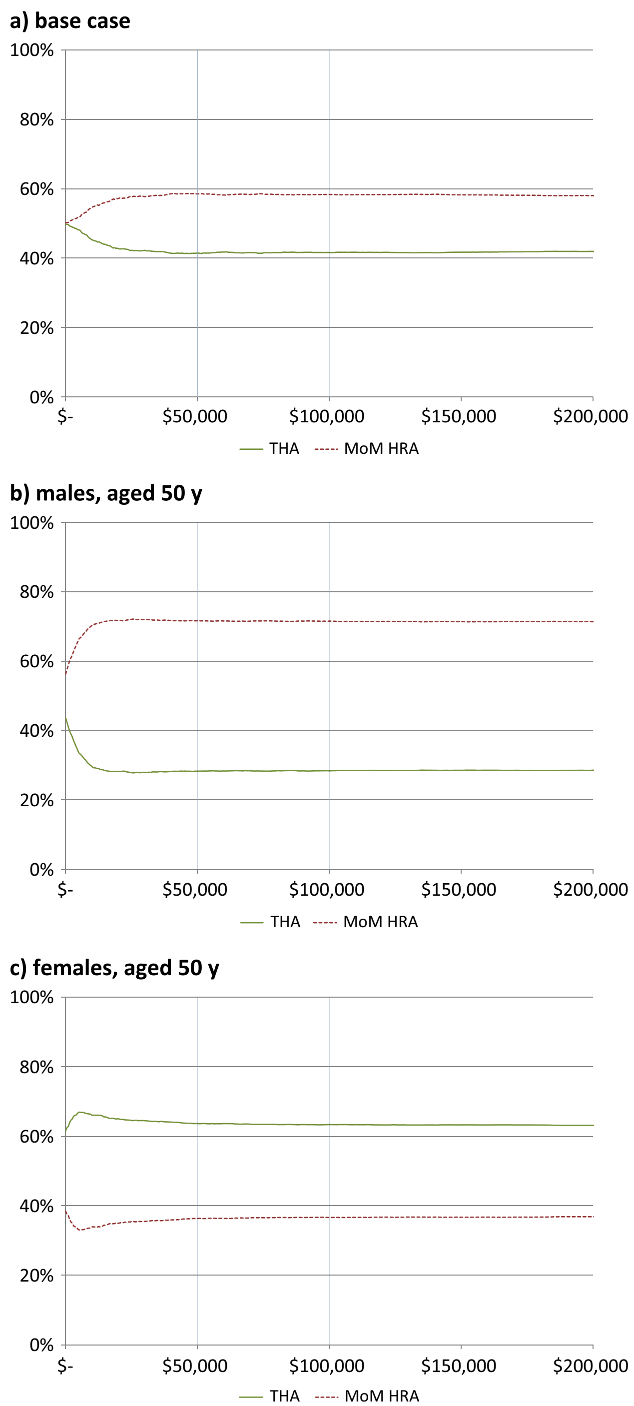

Fig. 3 – Cost-effectiveness acceptability curves. MoM HRA, metal-on-metal hip resurfacing arthroplasty; THA, total hip arthroplasty.

performance for MoM HRA in men [11,22]. This sex effect should be interpreted with care because others have reported that the effect disappeared after adjustments for component size [11,50–52]. In this study, the sample sizes by component were too small for subgroup analysis. MoM HRA rather than THA is found to be particularly suitable for patients with a large femoral offset or a wide femoral canal [11], and these characteristics are often related to male sex [4]. The preference for male sex toward MoM HRA is also a result of reported increased rates of revision and a generally higher prevalence of failure for women [53]; a poorer bone density in women results in a higher rate of femoral fractures [51,52]. McGrory et al. [54] reported a 2.5 times lower risk for MoM HRA failure in men versus women, regardless of age. Conversely, the risk of failure in THA is higher in men [10,12].

Taking into account age differences, MoM HRA was preferable in younger patients and THA was preferable in older patients. This is in accordance with device choices seen in practice; the majority of THAs were performed in people older than 65 years [10]. The increasing need for THA in younger patients led to the development of MoM HRA. Because younger patients are more likely to outlive their devices and subsequently require a surgical revision [10], MoM HRA has emerged as an alternative to THA [6].

Although RCTs are considered the gold standard for informing economic evaluation, they are of limited use in this scenario due to the nature of the procedures [55]. In addition, long-term follow-up is necessary to observe time until failure and post-revision effects. Unfortunately, long-term RCTs are difficult to realize. In addition, the technology changes rapidly, making it challenging to get useful results from a long-term RCT. With decision analysis it was possible to assess the cost-utility of MoM HRA by sex and age over a longer time horizon.

The review by Bozic et al. [2] reported the limited quality of THA economic evaluations. Only 12% discounted their results and only 22% performed sensitivity analyses [2]. Our study included both discounting and sensitivity analyses, to reflect uncertainty around the ICERs of MoM HRA compared with THA.

The primary limitation of this study is the difficulty in comparing patients with MoM HRA to patients with THA because procedure indications are often age- or sex-related. To address this, HIP included only women 55 years or younger and men 65 years and younger. To reduce the sex and age differences in SF-6D scores, utilities were adjusted for baseline differences. The age- and sex-specific subgroup analyses were rerun by using utilities from HIP that were not age- and gender-specific (Table 2). This analysis suggested that results are sensitive to utility values. A limitation of this study is the absence of SF-6D utility scores after revision surgery. No reliable long-term utility values were found in the literature. We therefore applied the ratio of post–primary surgery:postrevision EuroQol five-dimensional questionnaire scores from two other studies to our post–primary surgery values to estimate postrevision scores [35,36]. We would not expect this adjustment to have a large impact on the results because it affects only those who have revision, which is a small proportion and these occur later in time.

The long-term consequences of metallosis and the probability of developing cancer in the model were not included [8]. The discussions around health risks of MoM HRA should be addressed while making decisions.

Because of the small number of reported complications, complication probabilities in the model were assumed to be similar for all subgroups. This is confirmed in the literature [56], but it might be a limitation. Future studies should pay more attention to complication probabilities in different subgroups.

Another limitation is the maximum number of potential surgeries patients in the MoM HRA and THA strategies could undergo in the model. After primary MoM HRA a patient could have up to four surgeries in addition to the primary surgery, whereas a patient with THA could have up to two additional surgeries. Because surgery is costly, this could potentially bias against MoM HRA.

We estimated costs from a health care perspective; thus, no societal costs were included in the analysis. This may be seen as a limitation because it is well known that patients with hip OA requiring surgery often also have societal costs. The costs of hospital treatment, however, capture most of the total costs [57]. To investigate the cost-utility from a societal perspective, a recommendation for future research should be to add societal costs to the analyses.

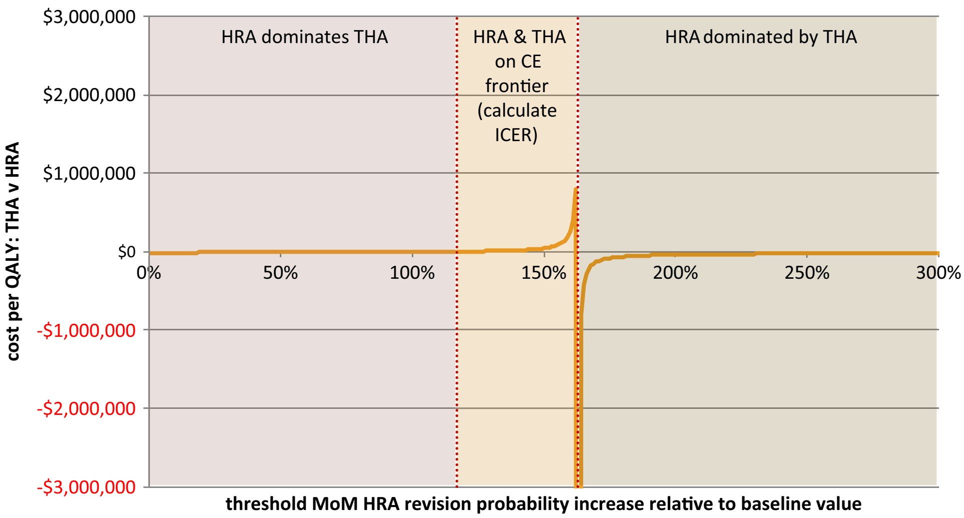

Fig. 4 – Threshold analysis for MoM HRA revision (base-case cycle 1 = 0.00889) and THA conversion (base-case cycle 1 = 0.00515) transition probabilities. Dotted lines represent threshold changes. CE, cost-effectiveness; ICER, incremental cost-effectiveness ratio; MoM HRA, metal-on-metal hip resurfacing arthroplasty; QALY, quality-adjusted life-year; THA, total hip arthroplasty.

Although lifetime evaluation is preferred as per economic evaluation guidelines, the time horizon of this study was 15 years due to a lack of reliable long-term data and because assumptions about the form and duration of longer term effects would be speculative, extrapolation beyond a 15-year time horizon was considered to introduce more uncertainty than justified for the decision problem at stake. A lifetime horizon is expected to be about 30 years for the base-case cohort of 50-year-olds.

The results of this study will inform decision makers about the cost-utility of MoM HRA versus THA for younger patients with OA. From an allocative efficiency viewpoint, no general preferred treatment option can be distinguished on the basis of current cost-effectiveness data. Results could be used to help inform Alberta Health Services in long-term policy issues regarding hip replacements in Alberta.

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Supplemental Materials

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