Revision Risk After Unipolar or Bipolar Hemiarthroplasty for Femoral Neck Fractures

An Instrumental Variable Analysis of 62,875 Procedures from the Australian Orthopaedic Association National Joint Replacement Registry

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Background: There remains much international practice variation regarding the choice of a unipolar or bipolar prosthesis design for displaced femoral neck fractures that are treated with hemiarthroplasty. The purpose of the present study was to compare revision rates following primary hemiarthroplasty for femoral neck fracture to determine if the unipolar hemiarthroplasty design increases the risk of revision arthroplasty for all causes.

Methods: Instrumental variable analysis was performed with use of data that had been entered into the Australian Orthopaedic Association National Joint Replacement Registry from September 1, 1999, to December 31, 2018. Sixty-two thousand, eight hundred and seventy-five patients with femoral neck fractures that were treated with primary modular unipolar or bipolar hemiarthroplasty procedure were analyzed. Hospital preference for prosthesis design in the 12 months prior to the index procedure was used as an instrument to adjust for unmeasured confounding. The primary outcome was time to first revision for any cause. Secondary analyses were performed on the reason for revision (infection, dislocation, periprosthetic fracture, or acetabular erosion), the use of cement femoral stem fixation, and the type of stem (polished or matte).

Results: Modular unipolar hemiarthroplasty was associated with a higher rate of revision at >2.5 years (hazard ratio [HR], 1.86; 95% confidence interval [CI], 1.46 to 2.36; p < 0.001), but there was no difference between the groups before 2.5 years (HR, 0.98; 95% CI, 0.85 to 1.13; p = 0.79). Protective factors for revision included female sex (HR, 0.82; 95% CI, 0.74 to 0.9), use of cemented fixation (HR, 0.69; 95% CI, 0.62 to 0.77), and surgery performed in a public hospital setting (HR 0.79; 95% CI, 0.70 to 0.89). Modular unipolar prostheses had a greater risk of revision for acetabular erosion, particularly in later time periods (HR at ≥5.5 years, 5.10; 95% CI, 2.40 to 10.83; p < 0.001), while being protective against periprosthetic fractures (HR, 0.72; 95% CI, 0.59 to 0.87; p < 0.001) at all time points. There was no difference in terms of the risk of revision for infection, dislocation, or stem type.

Conclusions: Bipolar hemiarthroplasty designs resulted in a lower risk of revision than unipolar designs. Unipolar hemiarthroplasties are justified for patients with femoral neck fracture and a shorter life expectancy (≤2.5 years).

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Evidence from randomized controlled trials (RCTs), registry analyses, and systematic reviews indicates that modular hemiarthroplasty with cement is now the standard of care for the treatment of displaced intracapsular femoral neck fractures in elderly patients with a shorter life expectancy or limited mobility[1-8]. Accordingly, these findings are now reflected in practice guidelines internationally[9-11]. However, there remains much international practice variation regarding the choice between unipolar and bipolar hemiarthroplasty designs[1,4,12]. The bipolar design, which features an additional articulating surface between the femoral stem and femoral head replacement, was introduced to reduce the incidence of acetabular erosion, a known long-term complication of hemiarthroplasty[13]. It was hypothesized that by reducing shear forces on the native acetabulum, bipolar prostheses would cause less

Disclosure: The authors indicated that no external funding was received for any aspect of this work. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/G189).

TABLE I Demographic Characteristics

	Modular unipolar	Bipolar
No. of patients	41,158	21,717
Sex		
Female		
Percentage of patients	70.7%	71.1%
Age* *(yr)*	82.9 ± 8.3	81.7 ± 8.8
Male		
Percentage of patients	29.3%	28.9%
Age* *(yr)*	81.6 ± 9.2	80.8 ± 9.8
BMI†		
Underweight (<18.5)	9.8%	8.2%
Normal (18.5 to <25)	51.8%	49.3%
Pre-obese (25 to <30)	27.6%	28.1%
Obese class 1 (30 to <35)	7.9%	10.7%
Obese class 2 (35 to <40)	2.0%	2.9%
Obese class 3 (≥40)	1.0%	0.8%
ASA class‡		
1	0.4%	0.5%
2	12.1%	13.8%
3	62.7%	60.5%
4	24.4%	24.8%
5	0.3%	0.4%

*The values are given as the mean and standard deviation. †Available since 2015. The values are given as the percentage of patients in each BMI category. The BMI values in parentheses are expressed in kg/m^2. ‡Available since 2012. The values are given as the percentage of patients in each ASA class.

acetabular erosion and hence better hip function postoperatively as well as lower rates of revision for the treatment of acetabular protrusion[14].

Clinical and registry studies have yielded conflicting results regarding both short and long-term outcomes. Previously published meta-analyses have provided unbalanced comparisons, often combining monoblock and modular prostheses, cemented and cementless fixation, and multiple study designs[3,15-18]. Despite their flaws, those meta-analyses have been unanimous in demonstrating equivalent rates of mortality, prosthetic dislocation, reoperation, and surgical complications for both designs[3,15-18]. Evidence from high-quality RCTs of modern cemented modular prostheses has demonstrated either similar or superior hip function in association with bipolar designs[19-22]. The majority of clinical trials have been limited to 2 years of follow-up (with the longest being 4 years) and may have been underpowered to detect differences because of small numbers. Most studies have demonstrated increased acetabular erosion in association with unipolar designs, but only one registry study has examined the rate of revision surgery for the treatment acetabular erosion, indicating a benefit in association with the bipolar design[23]. Longer-term follow-up of the same registry showed a higher risk of early revision for bipolar designs but an equivalent risk of revision over the long term[4]. These findings have led international experts to advocate the selective use of bipolar prostheses for elderly patients on the basis of expected years of life remaining by considering pre-morbid functional status and comorbidities[24].

Arthroplasty registries have proven to be a valuable adjunct to RCTs, especially when longer-term implant failure becomes apparent or event rates are low[25,26]. Because of the increasing incidence of, and improved survival following, femoral neck fractures[27,28], implant longevity for elderly patients with femoral neck fractures is an important consideration as revision surgery in this vulnerable population yields poor results[29]. The purpose of the present study was to compare the risk of revision arthroplasty for modern modular unipolar and bipolar prosthesis designs following primary hemiarthroplasty for the treatment of femoral neck fractures, using methods to adjust for known and unknown confounders and allowing causal inference. We hypothesized that modular unipolar prostheses would have a higher long-term risk of revision and, specifically, revision for acetabular erosion.

Materials and Methods

Study Design

Data from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) were used to calculate rates of revision after primary hemiarthroplasty for femoral neck fracture with use of either a modular unipolar or bipolar prosthesis. Data from September 1, 1999, to December 31, 2018, were included.

Statistical Analysis

The primary outcome was time to revision for any cause. Secondary analyses were performed on the reason for revision (infection, dislocation, periprosthetic fracture, or acetabular erosion), the use of femoral stem fixation, and the type of stem (polished or matte).

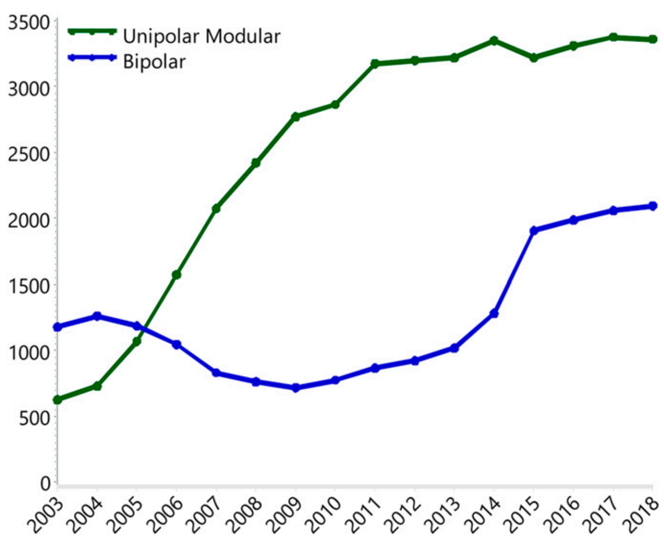


Fig. 1

Line graph illustrating the yearly usage of primary hemiarthroplasty for femoral neck fracture according to class.

TABLE II Reasons for Revision of Primary Hemiarthroplasties Performed for Femoral Neck Fracture

	Modular unipolar			Bipolar		
Reason for Revision	No. of Revisions	Percentage of Primary Hemiarthroplasties Revised for Each Reason (N = 41,158)	Percentage of Revisions Performed for Each Reason (N = 1,371)	No. of Revisions	Percentage of Primary Hemiarthroplasties Revised for Each Reason (N = 21,717)	Percentage of Revisions Performed for Each Reason (N = 745)
Infection	281	0.7%	20.5%	163	0.8%	21.9%
Prosthesis dislocation	267	0.6%	19.5%	146	0.7%	19.6%
Acetabular erosion	228	0.6%	16.6%	62	0.3%	8.3%
Fracture	223	0.5%	16.3%	186	0.9%	25.0%
Loosening	162	0.4%	11.8%	112	0.5%	15.0%
Pain	159	0.4%	11.6%	54	0.2%	7.2%
Other*	51	0.1%	3.7%	22	0.1%	3.0%
Total	1,371	3.3%	100%	745	3.4%	100%

*Includes osteolysis, incorrect sizing, instability, metal-related pathology, implant breakage, limb-length discrepancy, malpositioning, heterotopic bone, tumor, and wear of head.

Kaplan-Meier survival analysis was used to calculate the cumulative percent revision, and hazard ratios (HRs) from Cox proportional hazards regression models were used to make statistical comparisons of the rates of revision between modular unipolar and bipolar hemiarthroplasty. Time-varying HRs are presented when the proportional hazards assumption was not satisfied. Multivariable regression analyses were adjusted for age, sex, stem fixation (cemented or uncemented), and hospital type (public or private) to adjust for possible confounding. The AOANJRR commenced collection of patients' American Society of Anesthesiologists (ASA) physical status scores in 2012 and body mass index (BMI) in 2015; hence, these data were only available for a subset of patients and were not included in the analysis.

We conducted an instrumental variable analysis based on hospital preference for the use of bipolar or unipolar prostheses. Our instrument was the proportion of bipolar procedures among the total number of hemiarthroplasty procedures (modular unipolar and bipolar) performed at each hospital in the year prior to the index operation, according to a previously described method designed for time-to-event data[30,31]. We excluded procedures when <10 hemiarthroplasty procedures for femoral neck fracture had been performed at the operating hospital in the previous year. Patients who would have received a bipolar hemiarthroplasty at some institutions and unipolar hemiarthroplasty at others were therefore identified on the basis of the value of the instrument, thereby adjusting for unmeasured confounding (such

TABLE III Types of Revision of Primary Hemiarthroplasty for Femoral Neck Fracture

	Modular unipolar			Bipolar		
Type of Revision	No. of Revisions	Percentage of Primary Hemiarthroplasties with Each Type of Revision (N = 41,158)	Percentage of Revisions of Each Type (N = 1,371)	No. of Revisions	Percentage of Primary Hemiarthroplasties with Each Type of Revision (N = 21,717)	Percentage of Revisions of Each Type (N = 745)
Acetabular component	611	1.5%	44.6%	249	1.1%	33.4%
Total hip replacement (femoral/acetabular)	233	0.6%	17.0%	167	0.8%	22.4%
Head only	178	0.4%	13.0%	19	0.1%	2.6%
Femoral component	149	0.4%	10.9%	41	0.2%	5.5%
Bipolar head and femoral	43	0.1%	3.1%	97	0.4%	13.0%
Bipolar only	11	0.0%	0.8%	94	0.4%	12.6%
Cement spacer	56	0.1%	4.1%	41	0.2%	5.5%
Minor components	44	0.1%	3.2%	19	0.1%	2.6%
Removal of prostheses	40	0.1%	2.9%	18	0.1%	2.4%
Reinsertion of components	4	0.0%	0.3%	—	—	—
Cement only	1	0.0%	0.1%	—	—	—
Head/insert	1	0.0%	0.1%	—	—	—
Total	1,371	3.3%	100.0%	745	3.4%	100.0%

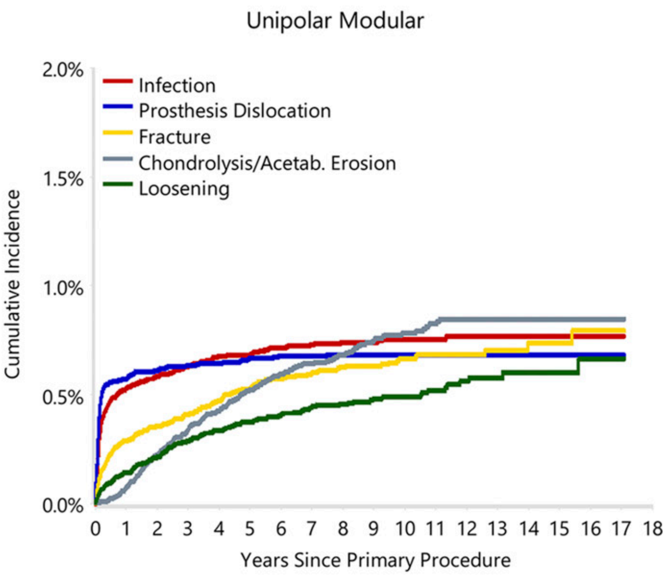


Fig. 2
Line graphs showing the cumulative rates of revision according to diagnosis.

as patient characteristics) that might influence prosthesis choice. The strength of the instrument was measured by determining whether increasing levels of the instrument were associated with changing levels of exposure, reported with use of the F statistic. An F statistic of >10 indicated acceptable strength.

The unadjusted Kaplan-Meier curves were produced with use of SAS (version 9.4; SAS Institute). Cox regression and instrumental variable analysis were performed with use of R (version 3.5.3; R Foundation for Statistical Computing).

Ethics

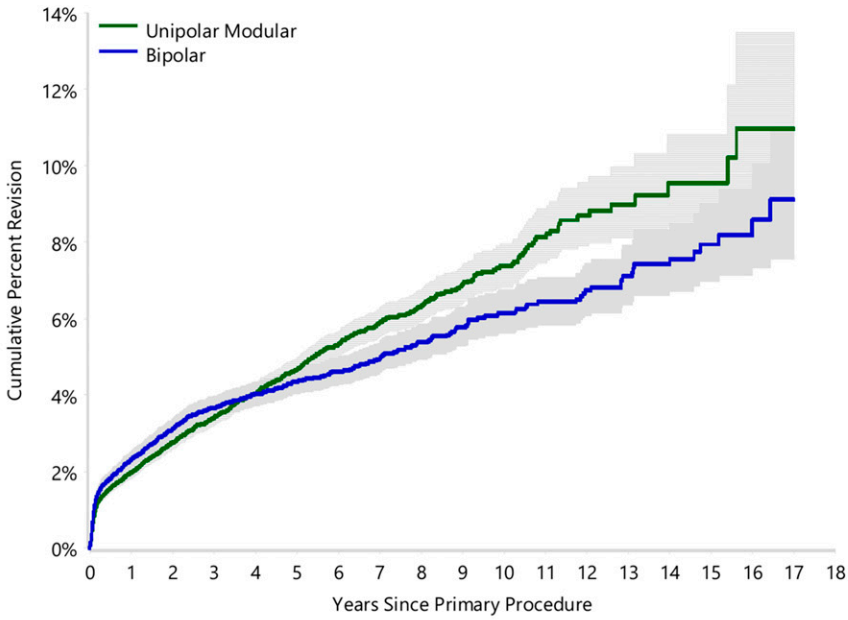
The AOANJRR is approved by the Commonwealth of Australia as a federal quality-assurance activity under section 124X of the Health Insurance Act, 1973. All AOANJRR studies are conducted in accordance with ethical principles of research (the Helsinki Declaration II).

Results

A total of 62,875 primary hemiarthroplasty procedures were included in the analysis, with nearly twice as many modular unipolar (65.5% of total) as bipolar (34.5% of total) prostheses used (Table I). The use of modular unipolar hemiarthroplasties has been more common in Australia beginning in 2006 (Fig. 1). Unipolar hemiarthroplasties were performed in slightly older patients, but the male:female ratio was similar in both groups. The reasons for revision are reported in Table II, and the types of revision are reported in Table III. When the reasons for revision were examined, a greater percentage of modular unipolar hemiarthroplasties was revised for acetabular erosion compared with bipolar hemiarthroplasties (0.6% versus 0.3%), while a lower percentage was reported for periprosthetic fracture in unipolar hemiarthroplasties compared with bipolar hemiarthroplasties (0.5% versus 0.9%) (Fig. 2). The most common type of revision in both groups was conversion to total hip replacement, with addition of an acetabular component alone being more common than addition of an acetabular component and exchange of a femoral component.

The Kaplan-Meier estimates of mortality for modular unipolar hemiarthroplasty at 1 year, 5 years, and 10 years were 24.7% (95% confidence interval [CI], 24.3% to 25.2%), 59.9% (95% CI, 59.3% to 60.4%), and 80.4% (95% CI, 79.8% to 80.9%), respectively. For bipolar hemiarthroplasty, the estimated mortality rates at 1 year, 5 years, and 10 years were 22.0% (95% CI, 21.4% to 22.5%), 54.2% (95% CI, 53.4% to 54.9%), and 75.9% (95% CI, 75.1% to 76.6%), respectively. In the unadjusted comparison, the risk of revision for modular unipolar hemiarthroplasty was lower than for bipolar hemiarthroplasty for the first 2.5 years after the primary procedure (HR, 0.88; 95% CI, 0.79 to 0.98). However, the risk of revision for modular unipolar hemiarthroplasty was higher than for bipolar hemiarthroplasty after 2.5 years (HR, 1.65; 95% CI, 1.32 to 2.07) (Fig. 3, Table IV).

When the Cox model was adjusted for sex, age, fixation (use of cement), and hospital, there was no difference in the risk of revision for the first 2.5 years after the primary procedure. However, the risk of revision for modular unipolar hemiarthroplasty remained higher than that for bipolar hemiarthroplasty after 2.5 years (HR, 1.76; 95% CI, 1.41 to 2.2). Cementless fixation had a higher risk of revision compared with cemented fixation for both modular unipolar and bipolar hemiarthroplasties at all time points (Fig. 4). The risk of revision for modular unipolar cemented hemiarthroplasty was 76% higher than that for bipolar cemented hemiarthroplasty at >2.5 years; there was no difference in the risk of revision at ≤2.5 years (Table IV). At all time points, the risk of revision for acetabular erosion was higher for modular unipolar hemiarthroplasty whereas the risk of revision for periprosthetic fracture was higher for bipolar hemiarthroplasty (Figs. 5 and 6).



Number at Risk	0 Yr	1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs	6 Yrs	7 Yrs	8 Yrs
Unipolar Modular	41158	27862	21765	16761	12703	9518	7013	5103	3628
Bipolar	21717	14943	11687	9077	7036	5575	4464	3612	2884

Number at Risk	9 Yrs	10 Yrs	11 Yrs	12 Yrs	13 Yrs	14 Yrs	15 Yrs	16 Yrs	17 Yrs	18 Yrs
Unipolar Modular	2585	1747	1160	718	434	277	175	99	44	11
Bipolar	2345	1898	1534	1219	910	641	417	233	97	32

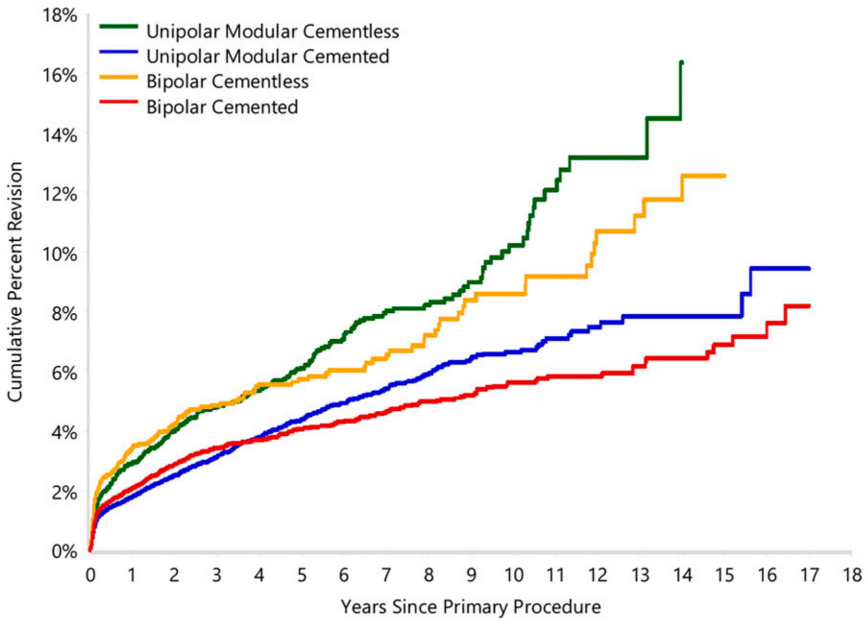
Fig. 3
Line graph and table showing the cumulative rates of revision of primary hemiarthroplasty (with 95% CIs) for femoral neck fracture according to class.

For the instrumental variable analysis, 6,553 procedures were excluded because <10 hemiarthroplasties had been performed at the hospital in the previous year. The remaining 38,065 modular unipolar and 18,257 bipolar prostheses were included in the analysis. The instrument demonstrated a very strong association between hospital and the type of hemiarthroplasty procedure performed (F = 89,078).

TABLE IV Hazard Ratios from Cox Proportional Hazards Model Comparing Primary Unipolar and Bipolar Hemiarthroplasty*

	Unadjusted		Adjusted		Instrumental Variable Cox Regression	
	HR (95% CI)	P Value	HR (95% CI)	P Value	HR (95% CI)	P Value
Unipolar vs. bipolar						
0-2.5 yr	0.88 (0.79, 0.98)	0.02	0.93 (0.84, 1.05)	0.27	0.98 (0.85, 1.13)	0.79
>2.5 yr	1.65 (1.32, 2.07)	<0.001	1.76 (1.41, 2.2)	<0.001	1.86 (1.46, 2.36)	<0.001
Age						
0-6 months			0.98 (0.97, 0.99)	<0.001	0.98 (0.97, 0.99)	<0.001
>6 months			0.95 (0.94, 0.95)	<0.001	0.94 (0.94, 0.95)	<0.001
Female vs. male			0.82 (0.74, 0.9)	<0.001	0.82 (0.74, 0.9)	<0.001
Cemented vs. cementless			0.69 (0.62, 0.77)	<0.001	0.69 (0.62, 0.77)	<0.001
Public vs. private hospital			0.8 (0.7, 0.9)	<0.001	0.79 (0.70, 0.89)	<0.001

*HR = hazard ratio, and CI = confidence interval.



Number at Risk		0 Yr	1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs	6 Yrs	7 Yrs	8 Yrs
Unipolar Modular	Cementless	6304	4643	3858	3154	2525	1938	1509	1155	859
	Cemented	34854	23219	17907	13607	10178	7580	5504	3948	2769
Bipolar	Cementless	3702	2653	2123	1721	1358	1058	849	657	535
	Cemented	18015	12290	9564	7356	5678	4517	3615	2955	2349

Number at Risk		9 Yrs	10 Yrs	11 Yrs	12 Yrs	13 Yrs	14 Yrs	15 Yrs	16 Yrs	17 Yrs	18 Yrs
Unipolar Modular	Cementless	610	399	261	153	76	45	19	7	2	0
	Cemented	1975	1348	899	565	358	232	156	92	42	11
Bipolar	Cementless	422	340	283	228	165	110	56	25	8	4
	Cemented	1923	1558	1251	991	745	531	361	208	89	28

Fig. 4

Line graph and table showing the cumulative rates of revision of primary hemiarthroplasty for femoral neck fracture according to class and fixation.

Again, the analysis was adjusted for age, sex, fixation, and hospital type. The instrumental variable analysis demonstrated that patients selected for modular unipolar hemiarthroplasty had a higher revision rate after 2.5 years (HR, 1.86; 95% CI, 1.46 to 2.36) but not before 2.5 years (HR, 0.98; 95% CI, 0.85 to 1.13) (Table IV). The percentage change between the adjusted Cox regression and instrumental variable models was +10%, indicating a stronger treatment effect.

As the bipolar prostheses demonstrated a higher risk of revision for periprosthetic fracture, we performed an exploratory analysis to determine whether stem type (polished or matte) was an explanatory variable. We did not find a relationship and hence excluded stem type from the adjusted comparisons (see Appendix for full analysis).

Discussion

In this analysis, we found a higher risk of revision for modular unipolar hemiarthroplasty compared with bipolar hemiarthroplasty in both unadjusted and adjusted models. When unmeasured confounding was accounted for using an instrumental variable analysis, the association was found to be stronger, with the rate of revision being nearly twice has high for unipolar hemiarthroplasty than for bipolar arthroplasty after the first 2.5 years following surgery.

Previously published time-to-revision data for hemiarthroplasties performed for femoral neck fracture are limited to analyses from the Swedish Hip Arthroplasty Register (SHAR)[4], the Norwegian Hip Fracture Register (NHFR)[12], the Dutch Arthroplasty Register (LROI)[32], and the AOANJRR[1]. The proportion of unipolar prostheses used differs by jurisdiction, indicating substantial international variation in practice. The reported use of unipolar hemiarthroplasty varies widely as a proportion of procedures among the Netherlands, Australia, and Sweden (79%, 65.5%, and 42%, respectively)[1,4,33]. In Norway, bipolar hemiarthroplasties are used almost exclusively (>99% of recorded

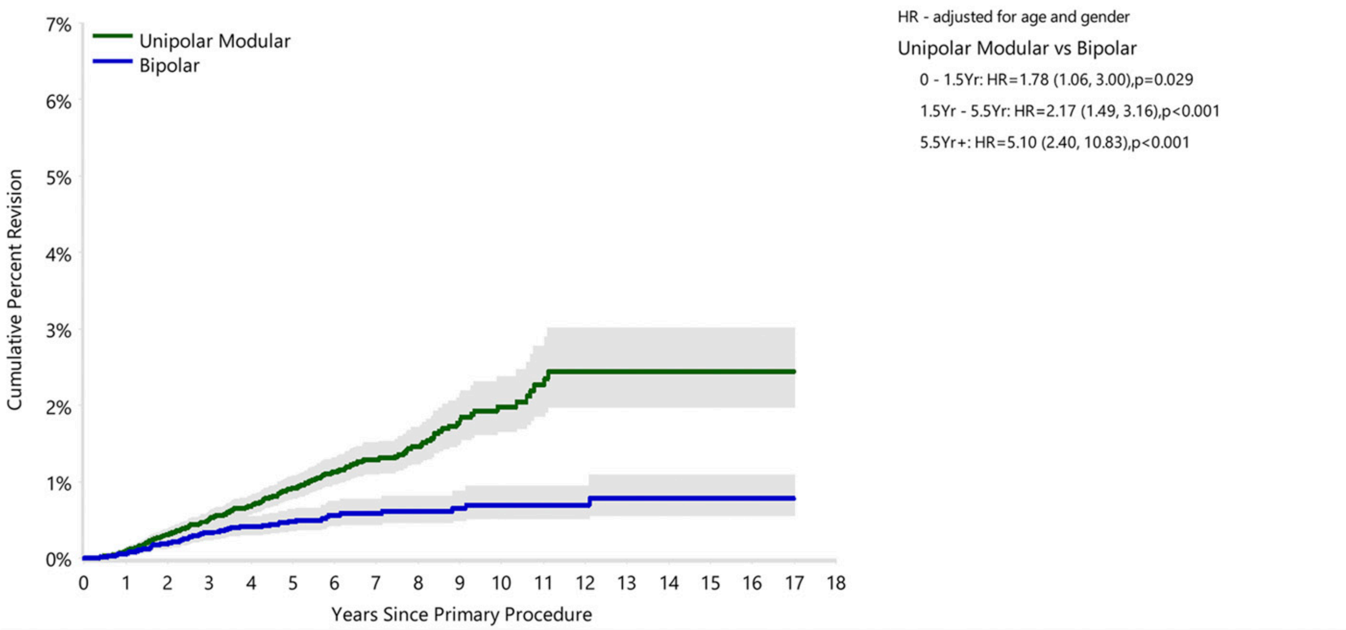


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Fig. 5

Line graph and table showing the cumulative rates of revision (with 95% CIs) for acetabular erosion according to class.

procedures)[5,34]. Consistent with our analysis, the 5-year unadjusted rate of prosthesis survival for cemented hemiarthroplasty implants is highest in the Norwegian registry, at 96.7% (95% CI, 96.3% to 97.1%), because of the nearly universal use of bipolar hemiarthroplasty[34]. In comparison, the rates are 94.9% (95% CI, 94.5% to 95.4%) in Sweden and 95.4% (95% CI, 95.2% to 95.7%) in Australia, which use a combination of modular unipolar and bipolar prostheses.

In contrast to our findings based on AOANJRR data, the LROI does not identify an increased risk of revision associated with unipolar hemiarthroplasty[33]. While the SHAR has previously demonstrated an increased risk of revision at up to 2 years following bipolar hemiarthroplasty[23], the risk of revision equilibrated after this time[4]. The observed differences have previously been attributed to differences between registries in terms of the demographic characteristics of their hemiarthroplasty populations[33]. However, the mean age of patients receiving primary hemiarthroplasty for femoral neck fracture in the AOANJRR is similar to the corresponding values in the LROI and NHFR (range, 82.5 to 83.0 years); all 3 registries have slightly younger cohorts than the SHAR (mean age, 84.1 years). Similarly, the female composition of each registry ranges from 70% to 74%[1,33,34]. Therefore, age and sex are not explanatory factors for differences between the registries.

All 4 registries capture different demographic and procedural details at the time of primary hemiarthroplasty for femoral neck fracture and therefore use different risk factors when estimating revision. Increasing age, increasing comorbidities (ASA class), male sex, and use of an uncemented stem have been reported as risk factors for all-cause revision[1,4,5,8,32,33]. When the surgical approach has been recorded, anterolateral and lateral approaches have had a lower risk of revision for dislocation in comparison with the posterior approach[4,23]. However, surgical approach does not appear to influence the incidence of postoperative periprosthetic fracture[23,33]. Our study replicates findings from previous analyses of the SHAR, demonstrating a protective effect of bipolar hemiarthroplasty against acetabular erosion, but a higher risk of periprosthetic fracture compared to unipolar hemiarthroplasty[23]. The reason for the difference between bipolar and unipolar hemiarthroplasty in terms of the periprosthetic fracture rate is not clearly understood. Initially, we hypothesized that differences in stem type (polished or matte) may have explained the increased risk of periprosthetic fracture associated with bipolar

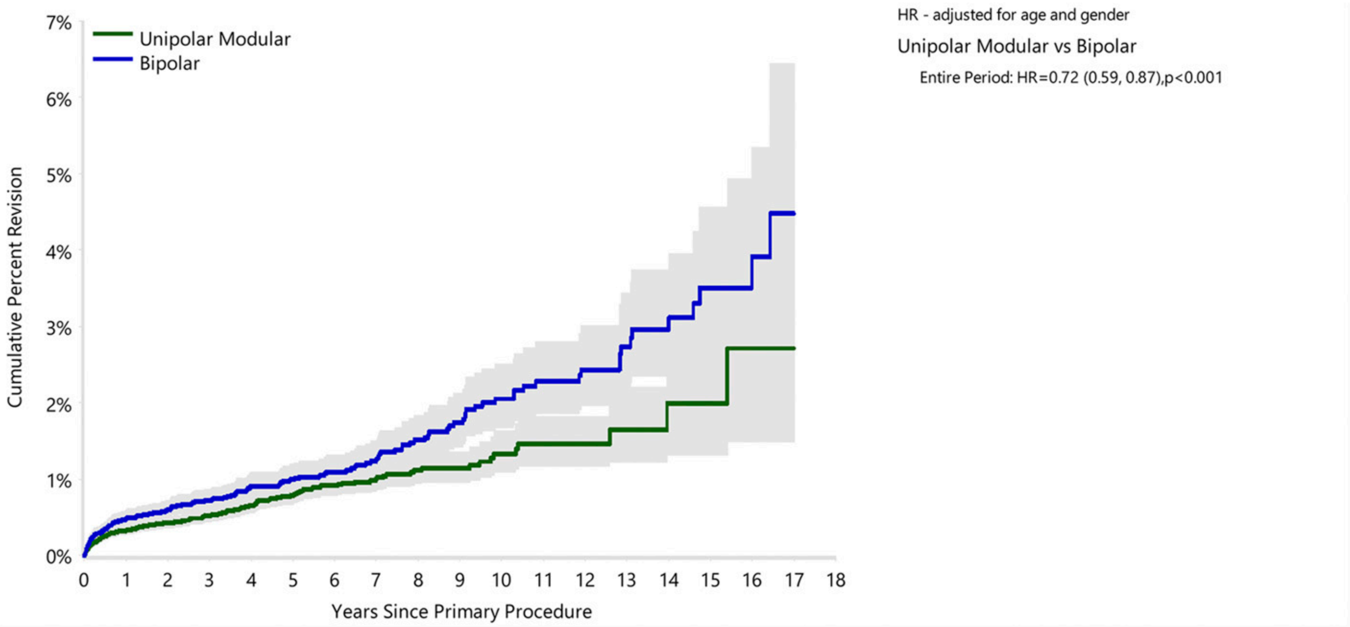

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Fig. 6

Line graph and table showing the cumulative rates of revision (with 95% CIs) for fracture according to class.

hemiarthroplasty. However, our analysis refuted that hypothesis (see Appendix). It is possible that the bipolar implant may lead to increased range of motion and activity levels, subsequently increasing the risk of periprosthetic fracture. However, that theory is not currently supported by RCTs, which have unanimously demonstrated equivocal hip function and quality-of-life scores at the time of follow-up[3,17]. Importantly, our methods adjust for unmeasured confounding such as differences in activity levels. We could not find any published data directly comparing bipolar and unipolar hemiarthroplasty in terms of proprioceptive function or fall risk.

In our cohort, the rate of revision for acetabular erosion was 0.6% following modular unipolar hemiarthroplasty and 0.3% following bipolar hemiarthroplasty. Acetabular erosion is an established reason for revision in the SHAR and AOANJRR[1,23] and has been reported in multiple RCTs[19,20,35]. The theoretical decrease in acetabular erosion provided by an additional articulating surface has been confirmed prospectively with use of stereographic roentgenograms[21]. However, a slightly reduced rate of acetabular erosion may not justify the use of a more expensive prosthesis in its own right. In Australia, there is a $916 USD price difference between the most commonly used bipolar and unipolar prostheses according to publicly available government prosthesis rebate data ($1 USD = $1.55 AUD as of May 7, 2020)[36]. Given that revision for acetabular erosion is a rare event and bipolar prostheses increase the risk of periprosthetic fracture, it is probable that there is no cost benefit to using bipolar prostheses for the treatment of femoral neck fracture in patients with a limited life expectancy (≤2.5 years). As we are limited to comparisons of small RCTs with short-term follow-up and registries that do not record the rate of acetabular erosion, we cannot be sure what percentage of patients develop symptomatic acetabular erosion in the long term that would be improved by revision arthroplasty. This cost remains unaccounted for in all analyses published to date.

The strengths of the present study include the use of a comprehensive national database of procedures, with a larger cohort of hemiarthroplasties than previous reports. By using an unselected national cohort, we have maximized external generalizability to reflect actual clinical practice. The 2 cohorts had similar demographic characteristics, and we are confident that selection bias has been minimized as the results were consistent between the Cox regression and instrumental variable analyses. The instrumental variable analysis was robust, allowing causal inferences to be made.

The main limitation of the present analysis is the use of observational data. The use of an instrumental variable analysis allowed us to account for unmeasured confounding by indication and to make causal inferences for observational data, addressing the main limitation of registry studies. Additionally, the statistical methods did not take into account multiple surgical procedures by individual surgeons. Our findings differ from the results of RCTs, which have inconsistently demonstrated a protective effect of bipolar hemiarthroplasty with respect to acetabular erosion. The difference in revision due to acetabular erosion occurs after 2.5 years, which exceeds the duration of follow-up for most RCTs in this patient population. Despite our much longer duration of follow-up, questions regarding hip function and health-related quality-of-life measures remain unanswered. A registry-nested RCT of unipolar versus bipolar hemiarthroplasty that includes patient-reported outcomes may prove to be the best means of determining the association between acetabular erosion and the risk of revision in the long term. We suspect that there is a cohort of patients with symptomatic acetabular erosion who are deemed too unwell to undergo a revision procedure, and these patients remain unaccounted for in all analyses to date.

In conclusion, we found a reduced risk of revision arthroplasty in association with the use of bipolar hemiarthroplasty as compared with modular unipolar hemiarthroplasty after 2.5 years and found that this association is causal in nature. The use of the more expensive bipolar prosthesis when treating femoral neck fracture may be justified for patients with a longer life expectancy.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/G190). ■

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