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## Title

Outcomes of hip and knee replacement surgery in private and public hospitals in Australia

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**Short Title:** Hospital Variation in Joint Replacement Outcomes

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## **Abstract**

*Introduction:* This study determined the contributing factors of hospital sector (private versus public) variation in revision rates after elective total hip replacement (THR) for hip fracture, and elective total knee replacement (TKR).

*Methods:* Using data from a large national arthroplasty registry, funnel plots for hospitals were generated, displaying the proportion of revised primary procedures. The proportion of outliers for each distribution was defined as outside the upper 99.7% confidence limit.

Survival analyses determined differences between hospital sector revision rates separately for implants with the lowest revision rate, and for all other implants. Multivariate Cox regression determined the role of hospital sector in revision, adjusting for possible confounders.

*Results:* For THR performed for osteoarthritis, 17.4% of private and 4.4% of public hospitals were outliers. For TKR performed for osteoarthritis, 19.6% of private and 10.0% of public hospitals were outliers. For THR for fractured neck of femur (FNF), 8.1% of private and 0.0% of public hospitals were outliers. Adjusted and unadjusted Kaplan Meier (KM) analyses showed higher THR revision rates in private hospitals for osteoarthritis and FNF, but no difference when restricted to the 10 prostheses with the lowest revision rate. The KM

analysis of TKR showed higher revision rates for private hospitals, with the association reversing when restricted to prostheses with the lowest revision rate.

*Conclusions:* Considerable variation was seen in the revision rate after THR and TKR between hospital sectors in Australia. The variation was largely due to differences in prosthesis selection.

**Key words:** *Hip, knee, revision outcomes, surgeon, hospital, prosthesis*

## **Introduction**

Over 100,000 hip and knee replacement procedures are performed annually in Australia. Health insurance is a two-tiered system in Australia, with universal coverage for all residents under Medicare, and with just over half of the population also having private health insurance.<sup>1</sup> Approximately two-thirds of hip and knee replacement procedures are performed in private hospitals by specialist orthopaedic surgeons. Joint replacement surgery in public hospitals is often performed by orthopaedic trainees under the supervision of specialist surgeons.

The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) records nearly 100% of joint replacement procedures performed in Australia and reports on rates and reasons for revision (repeat) joint replacement surgery and on mortality.

Some reports have compared rates of readmission or patient satisfaction between private and public hospitals but there are no reports available on the relative performance of private versus public hospitals using revision surgery as the outcome.<sup>2-6</sup> This study aims to

compare the rate of revision following primary hip and knee replacement surgery between private and public hospitals in Australia.

## **Methods**

Data from the AOANJRR was used to calculate rates of revision after primary total hip replacement (THR) and primary total knee replacement (TKR) for osteoarthritis (OA), and primary THR for fractured neck of femur (FNF), and each procedure group was analysed separately. Data from 1 January 2003 to 31 December 2016 were used. Funnel plots were used to explore inter-hospital variation in the overall proportion of primary procedures revised and the proportion of public and private hospitals lying outside the upper 99.7% confidence limit, based on the variation in the underlying data. To reduce any bias from differences in length of follow up between hospitals, and to explore variation in early revision, the funnel plot analysis was repeated, restricted to revision within 2 years of primary surgery.

Kaplan Meier survival analysis was used to calculate the cumulative percent revision (CPR) and Cox proportional hazards regression was performed to compare outcomes between private and public hospitals. All hospitals performing THR or TKR with at least 50 procedures reported were included.

All regression analyses were adjusted for age and sex. Other variables known to be associated with revision for a TKR (use of a prosthesis with higher than anticipated rate of revision [HTARR] as defined by the AOANJRR<sup>7</sup>, use of patella replacement, type of stability,

type of fixation, type of polyethylene and ASA grade) and THR (head size, type of fixation, bearing surface, use of a prosthesis with HTARR) were included with age and sex in a multivariate regression model to explore possible confounding.

Subgroup analyses were performed using only the 10 prosthesis combinations with the lowest CPR at 5 years, and separately using all other prosthesis combinations to explore the role of prosthesis choice in any differences seen. The number of prosthesis combinations (10) allowed a balance between including a broad variety of prostheses and providing large enough numbers for analysis, and isolating a group based on performance.

### *Ethics*

The AOANJRR is a declared Commonwealth of Australia 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**

Data from 164 private and 142 public hospitals were used in the analysis (296 hospitals for the elective THR analysis, 303 hospitals for the TKR analysis and 104 hospitals for the hip fracture analysis). For elective THR performed for osteoarthritis, 28 private hospitals (17.4%) and 6 public hospitals (4.4%) lay outside the upper 99.7% confidence limit for the overall proportion of primary cases revised. For TKR performed for osteoarthritis, the corresponding numbers are 32 (19.6%) for private hospitals and 14 (10.0%) for public

hospitals. For THR for FNF, the corresponding numbers are 3 (8.1%) for private hospitals and 0 (0.0%) for public hospitals (Figure 1abc).

Restricting the analysis of overall revision rate to revision surgery within 2 years of the primary procedure, for THR, 17 (10.6%) private hospitals and 3 (2.2%) public hospitals were outside the upper 99.7% confidence limit (Figure 2a). For TKR, the corresponding numbers are 26 (16.0%) for private hospitals and 10 (7.1%) for public hospitals. For THR for FNF, the corresponding numbers are 2 (5.4%) for private hospitals and 0 (0.0%) for public hospitals (Figure 2abc).

For Cox regression analysis of THR performed for osteoarthritis, the hazard ratio for revision after 3 months in private hospitals compared to public hospitals (adjusted for age and sex) was 1.31 (95% CI 1.25, 1.37; Figure 3a). For TKR, the revision rate was lower in private hospitals for the first 6 months, but higher at several time periods after 6 months (Figure 3b). For THR performed for FNF, the revision rate was higher in private hospitals at all time points (hazard ratio 1.40, 95% CI 1.21, 1.61) (Figure 3c).

Secondary multivariate Cox regression analyses including possible confounders (see Methods) showed similar results (Appendix 1): public hospitals had a significantly lower rate of revision than private hospitals after 3 months for TKR, and at all times for elective THR and for THR for FNF. Multivariate analyses were restricted to data from the last five years as ASA grade was only available for that time. Notably, in the multivariate analyses, the use of a prosthesis identified as HTARR was strongly associated with revision rate, adjusting for all

other variables. However, despite higher use of HTARR prostheses in private hospitals, the association between private sector and increased revision was independent of the use of HTARR prostheses (Table 1).

The survival analysis was repeated using only the ten prosthesis combinations (e.g. femoral and tibial combination for a knee replacement) with the lowest cumulative percent revision at 5 years. For this analysis, the rate of revision after THR for osteoarthritis is lower in private hospitals in the first month but not significantly different to public hospitals at all other times (Figure 4a). For total knee replacement, the rate of revision is lower in private hospitals in the first 3 months and after 1.5 years (Figure 4b). For THR performed for FNF there is no difference in the rate of revision between private and public hospitals when the 10 prostheses with the lowest rate of revision at 5 years are used (Figure 4c).

## **Discussion**

Our study showed higher rates of revision surgery after primary THR and TKR in private hospitals compared to public hospitals. However, when restricted to prosthesis combinations with low rates of revision, the rate of revision was not higher in private hospitals at any time. Other variables known to affect revision rates did not explain the difference in revision rates between public and private hospitals.

There are several reasons why rates of revision may vary between public and private hospitals. Implant selection is likely to differ between private and public hospitals. In private hospitals, implant choice is largely dictated by individual surgeons whereas in public

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hospitals, mechanisms may exist to restrict access to more expensive prostheses and to newer prostheses, and the range of prostheses available may also be restricted. Our findings show that prosthesis choice is likely to be the main cause for the higher rate of revision surgery seen in private hospitals, due to surgeons in private hospitals choosing prostheses with higher rates of revision, beyond those identified as HTARR. The process of identifying HTARR prostheses is rigorous, and there are many prosthesis combinations with higher than average rates of revision that do not meet the benchmark for HTARR status.

Secondly, surgery in public hospitals is often performed by trainee surgeons who may be expected to have a higher rate of revision and this may explain the lower rates of TKR revision in private hospitals when matched for prostheses. Previous research, however, has not shown a higher rate of arthroplasty revision amongst trainee surgeons.<sup>8,9</sup>

Thirdly, expectations and demands of private patients may differ from public patients. Combined with greater access to care (not just access to consultants and private hospitals, but greater ability to take time off work and arrange for carers), this may increase the rate of revision in the private sector.

Other factors (described above) may also have a role in explaining the differences seen, however the large size of the data set, the consistency of the findings on multivariate analysis, and the loss (or reversal) of the association when adjusting for prosthesis choice, suggest that prosthesis choice (whether by hospital or by surgeon) is an important determinant of the difference in revision rates between public and private hospitals. This

finding highlights the need to consider implant performance in the decision-making process, and the possible role of benchmarking in implant selection.

### **Conclusions**

We conclude that differences in the rate of revision between private and public hospitals after primary hip and knee replacement surgery are largely explained by prosthesis choice, rather than hospital type. We suggest that implant choice remains a strong factor in reducing the need for revision joint replacement surgery.

### **Acknowledgements**

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### **Disclosure Statement**

The authors have nothing to declare.

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## Tables

**Table 1.** Use of a prosthesis with higher than anticipated rate of revision (HTARR) in private and public hospitals.

## Figure legends

### Figure 1.

- a.** Funnel plot of revision of primary total hip arthroplasty performed for osteoarthritis by hospital.
- b.** Funnel plot for revision of primary total knee arthroplasty performed for osteoarthritis by hospital.
- c.** Funnel plot of revision of primary total hip arthroplasty performed for fractured neck of femur by hospital.

### Figure 2.

- a.** Funnel plot of revision within 2 years of primary total hip arthroplasty performed for osteoarthritis by hospital.
- b.** Funnel plot of revision within 2 years of primary total knee arthroplasty performed for osteoarthritis by hospital.
- c.** Funnel plot of revision within 2 years of primary total hip arthroplasty performed for fractured neck of femur.

### Figure 3.

- a.** Cumulative percent revision for primary total hip arthroplasty performed for osteoarthritis by hospital type.
- b.** Cumulative percent revision for primary total knee arthroplasty performed for osteoarthritis by hospital type.
- c.** Cumulative percent revision for primary total hip arthroplasty performed for fractured neck of femur by hospital type.

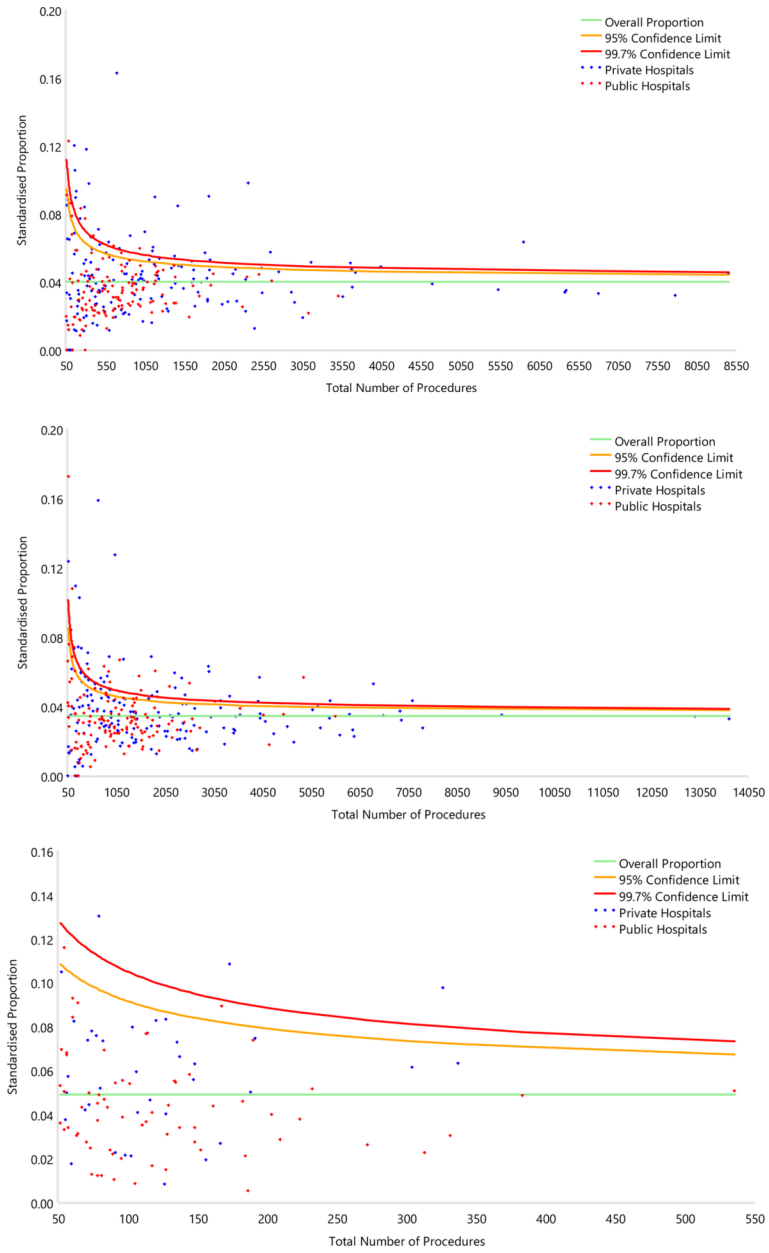
### Figure 4.

- a.** Cumulative percent revision for primary total hip arthroplasty performed for osteoarthritis using 10 prostheses with lowest revision rate at 5 years by hospital type.
- b.** Cumulative percent revision for total knee replacement for osteoarthritis using 10 prostheses with lowest revision rate at 5 years by hospital type.

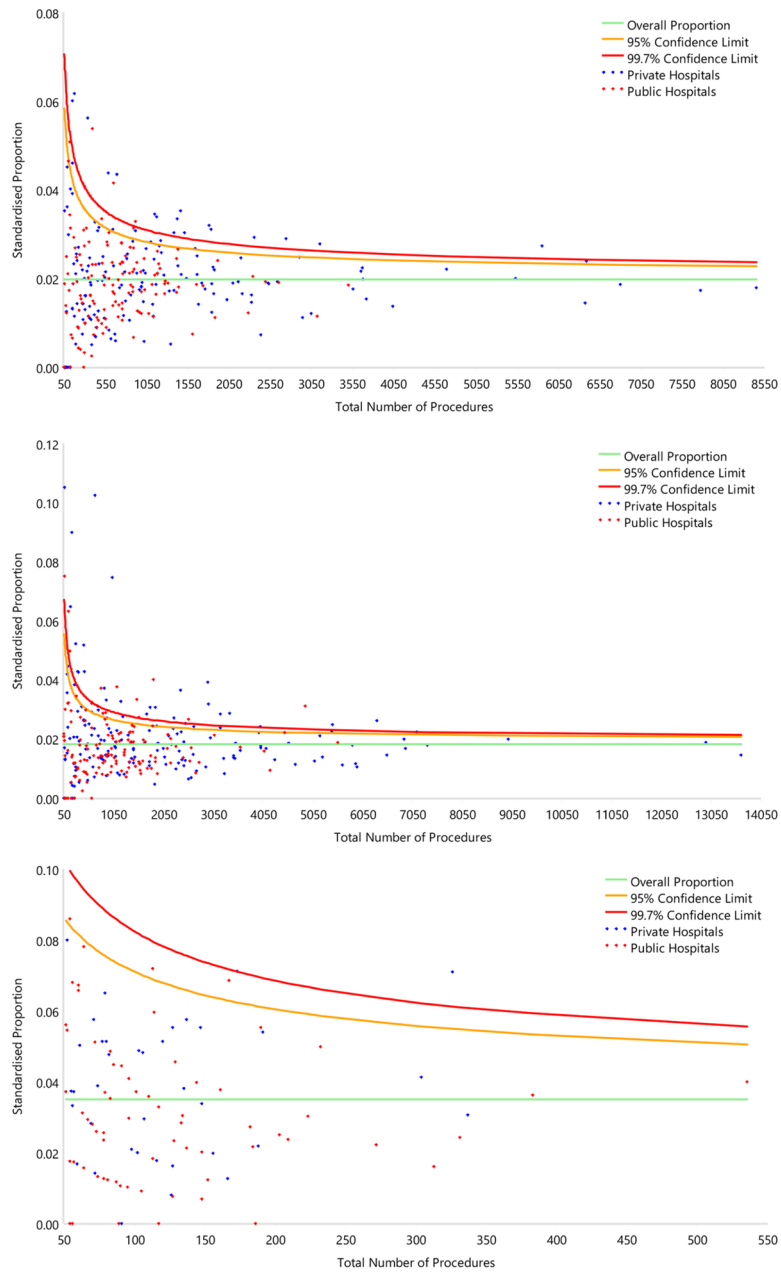
c. Cumulative percent revision for total hip replacement for fractured neck of femur using 10 prostheses with lowest revision rate at 5 years by hospital type.

### **Supporting Information**

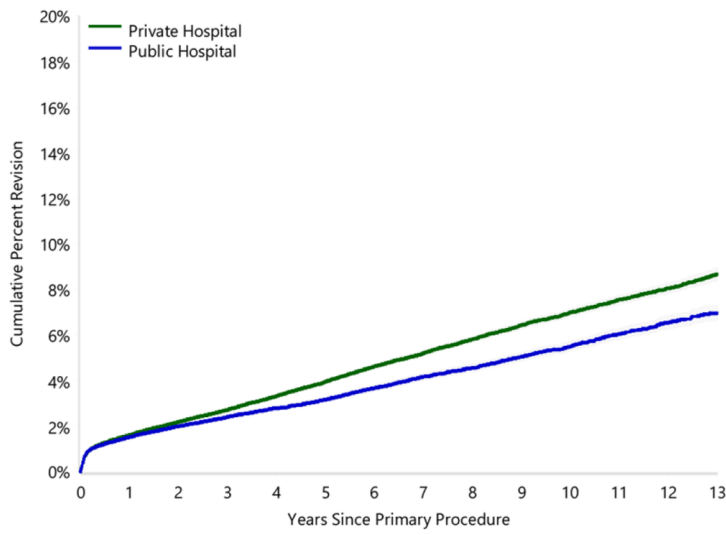
**Appendix S1.** Secondary multivariate Cox regression analyses.



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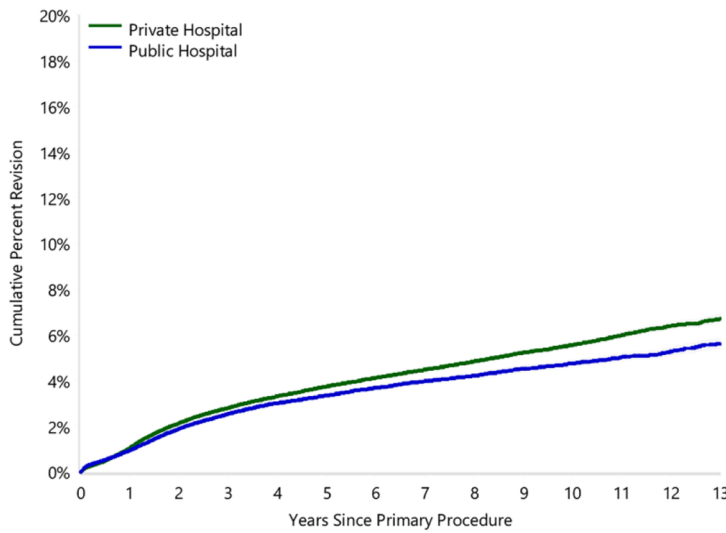


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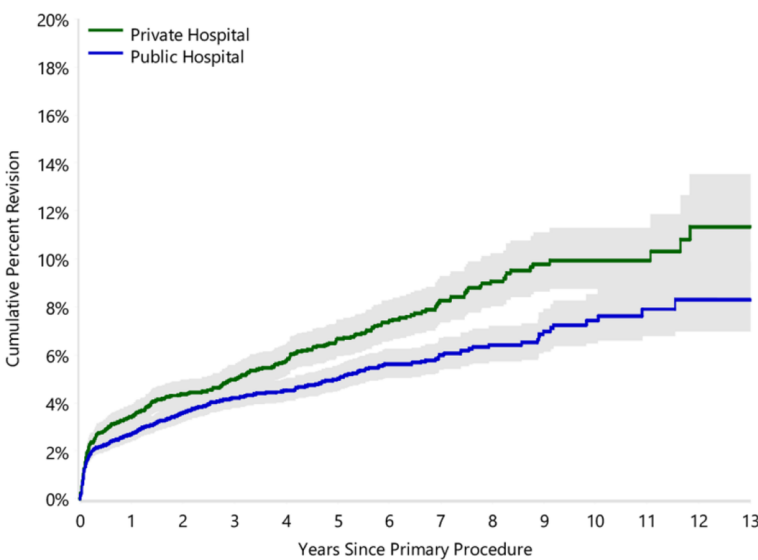
HR - adjusted for age and sex  
 Private Hospital vs Public Hospital  
 0 - 2Wk: HR=1.07 (0.92, 1.23),p=0.385  
 2Wk - 1Mth: HR=0.89 (0.79, 1.00),p=0.053  
 1Mth - 3Mth: HR=1.10 (0.97, 1.24),p=0.128  
 3Mth+: HR=1.31 (1.25, 1.37),p<0.001

Number at Risk	0 Yr	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	13 Yrs
Private Hospital	210828	184220	138555	99366	66029	29927	5808
Public Hospital	100931	88836	68381	50871	34854	16112	3098



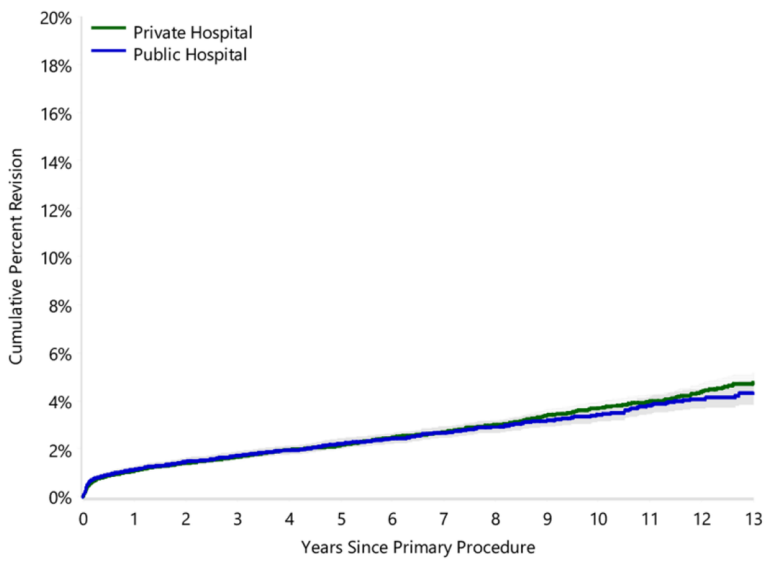
HR - adjusted for age and sex  
 Private Hospital vs Public Hospital  
 0 - 6Mth: HR=0.87 (0.80, 0.95),p=0.001  
 6Mth - 1Yr: HR=1.34 (1.22, 1.47),p<0.001  
 1Yr - 1.5Yr: HR=1.21 (1.11, 1.32),p<0.001  
 1.5Yr - 2.5Yr: HR=1.00 (0.93, 1.08),p=0.925  
 2.5Yr - 3Yr: HR=0.90 (0.79, 1.03),p=0.125  
 3Yr - 4Yr: HR=1.04 (0.93, 1.16),p=0.482  
 4Yr+: HR=1.24 (1.16, 1.33),p<0.001

Number at Risk	0 Yr	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	13 Yrs
Private Hospital	338259	297471	222071	158463	104436	45000	8199
Public Hospital	160642	142391	108647	79446	53476	23973	4106



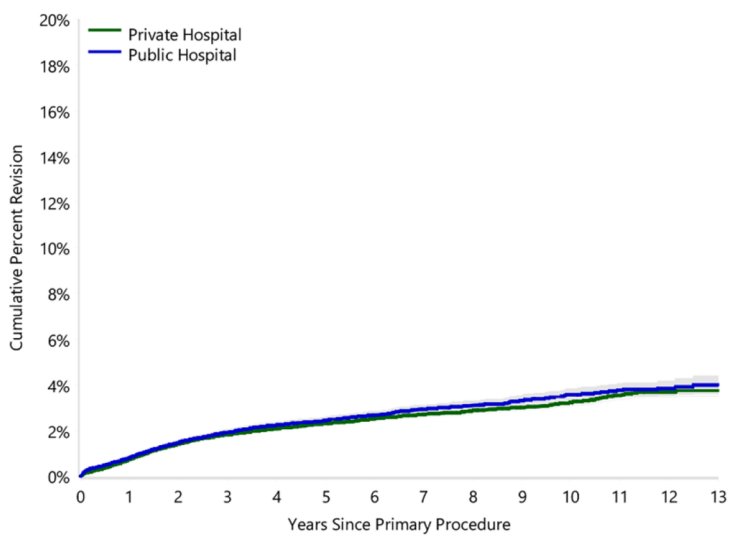
HR - adjusted for age and sex  
 Private Hospital vs Public Hospital  
 Entire Period: HR=1.40 (1.21, 1.61),p<0.001

Number at Risk	0 Yr	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	13 Yrs
Private Hospital	6118	4752	3188	2040	1183	431	63
Public Hospital	4634	4146	2916	1916	1334	497	71



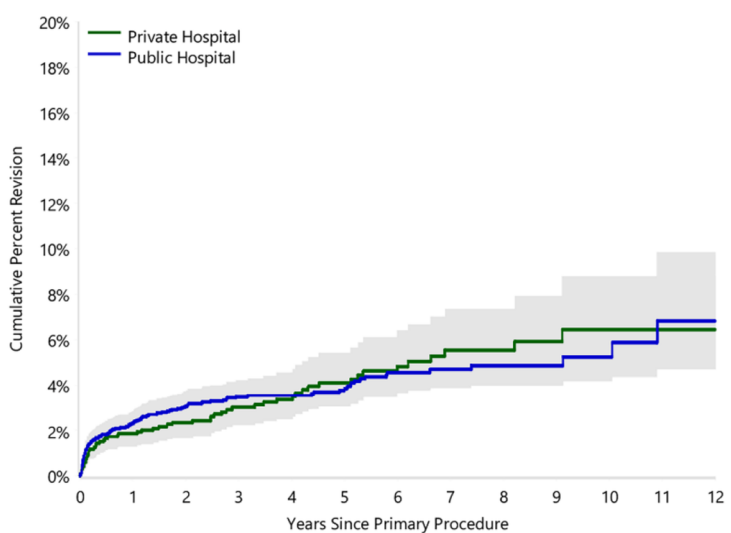
HR - adjusted for age and sex  
 Private Hospital vs Public Hospital  
 0 - 1Mth: HR=0.75 (0.60, 0.94),p=0.013  
 1Mth+: HR=1.09 (0.98, 1.21),p=0.115

Number at Risk	0 Yr	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	13 Yrs
Private Hospital	44909	40668	32326	24506	17536	9048	1671
Public Hospital	27522	24372	18710	14103	9953	4738	730



HR - adjusted for age and sex  
 Private Hospital vs Public Hospital  
 0 - 3Mth: HR=0.60 (0.50, 0.74),p<0.001  
 3Mth - 1.5Yr: HR=1.07 (0.95, 1.21),p=0.244  
 1.5Yr+: HR=0.89 (0.81, 0.99),p=0.033

Number at Risk	0 Yr	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	13 Yrs
Private Hospital	99701	87030	62335	39921	22725	7667	1068
Public Hospital	53865	45733	32051	20045	11197	4344	722



HR - adjusted for age and sex  
 Private Hospital vs Public Hospital  
 Entire Period: HR=1.00 (0.73, 1.37),p=0.999

Number at Risk	0 Yr	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	13 Yrs
Private Hospital	1634	1322	917	570	357	128	18
Public Hospital	3688	2927	1918	1191	631	158	19

Table 1. Use of HTARR prostheses in private and public hospitals

	Private	Public	% Difference	P-Value
THA for osteoarthritis				
HTARR Prostheses	25738 (12.2%)	11735 (11.6%)	0.58% (0.34%, 0.82%)	<0.0001
Other Prostheses	185090 (87.8%)	89196 (88.4%)		
THA for fracture				
HTARR Prostheses	882 (14.4%)	754 (8.0%)	6.47% (5.43%, 7.50%)	<0.0001
Other Prostheses	5236 (85.6%)	8730 (92.1%)		
TKA				
HTARR Prostheses	29854 (8.8%)	5031 (3.1%)	5.69% (5.57%, 5.82%)	<0.0001
Other Prostheses	308405 (91.2%)	155611 (96.9%)		