



Total Hip Replacement in Patients with Rheumatoid Arthritis: Trends in Incidence and Complication Rates Over 35 Years

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ABSTRACT

Introduction: Advances in rheumatoid arthritis (RA) management have made disease remission achievable. We evaluated trends in total hip replacement (THR) and postoperative outcomes in patients with RA in Western Australia (WA) over more than three decades.

Methods: This was a retrospective analysis of routinely collected prospective data from a state-wide registry containing longitudinally linked administrative health data based on International Classification of Diseases (ICD) diagnostic and procedural codes. We included

patients with two or more diagnostic codes for RA (between 1980 and 2015) and studied THR incidence rates (THR IR) and complication rates (revision, peri-prosthetic fracture, infection, venous thrombosis, and mechanical loosening). Survival rates were estimated by Kaplan–Meier method and predictors analyzed by Cox regression.

Results: We followed 9201 RA patients over 111,625 person-years, during which 1560 patients (16.9%) underwent THR. From 1985 to 2015, THR IR (per 1000 RA patient-years) decreased from 20.8 (95% CI 20.1–21.5) to 7.3 (95% CI 7.2–7.5), and 5-year THR-free survival increased from 84.3 to 95.3% (1980–2015). Ten-year prosthetic survival was 91.2%. Complication rates in the first 5 years post-THR decreased significantly from 13.1 to 3.7% ($p < 0.001$). Mechanical complications such as loosening and periprosthetic fracture rates decreased significantly ($> 35%$, $P < 0.05$), while infection and revision did not change over the observation period ($p > 0.05$).

Conclusions: Over the last 30 years in RA patients, THR IR and mechanical complication rates decreased significantly, but the medical complication of infection has not changed significantly.

Keywords: Total hip replacement; Rheumatoid arthritis; Incidence; Complications; Disease-modifying antirheumatic drugs; Epidemiology; Hospital records

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Key Summary Points

Background: Improved management of rheumatoid arthritis (RA) over the last decades has made disease remission an achievable goal

Hypothesis: The need for total hip replacement (THR) and the rate of post-operative complication rates in RA patients has decreased over the last decades.

Conclusions: In Australian RA patients, THR incidence rates decreased significantly over time and well before the introduction of bDMARDs. Rates for mechanical post-operative complications (aseptic loosening and periprosthetic fracture) decreased, while infection rates remain unchanged.

What was learned: More aggressive RA treatment with csDMARD over the last decades has been associated with a more than 50% decrease in the need for THR in RA. Whether increased use of bDMARDs further reduces the need for THR and rate of postoperative complications remains to be elucidated.

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic autoimmune disease where synovial inflammation causes painful swelling of the joints and may erode cartilage and bone [1–3]. Despite best management, RA patients can experience progressive disease and require total hip replacement (THR) [1, 4]. THR is an option considered on failure of the medical treatment protocol for RA and provides an objective measure of disease severity [1, 2, 4]. Recently, it has become clear that newer medications and management protocols have made low RA disease activity and remission achievable [2, 5–7].

THR incidence rates (THR IR) have been decreasing globally and as of 2010 rates were approximately 7 per 1000 person-years (PY) [8]. However, there is significant heterogeneity between studies and one proposed reason for this is variations in country or health system-specific factors [8]. This review noted a lack of population-based Australian studies examining THR rates in RA patients [8].

THR aims to relieve pain and improve function in RA patients, but the procedure still carries a risk of adverse outcomes (AO) despite introducing new postoperative protocols, surgical techniques, prosthesis designs, and preventative measures for infections [8–11]. Furthermore, RA patients are reported to have worse post-operative outcomes than osteoarthritis (OA) patients, which could potentially be influenced by rheumatic disease control [9, 12, 13], yet there remain relatively few studies examining prosthetic survival and adverse outcomes following THR in RA patients [8, 14, 15]. Given the relative sparsity of data on THR in RA patients, we performed a longitudinal state-wide population-based observational study of THR rates and complications in RA patients in Western Australia (WA) over the period 1980–2015.

METHODS

Patients

This observational study used linked administrative health data on patients in the Western Australian Rheumatic Disease Registry (WARDER). The registry, described in detail elsewhere [16], includes all patients in WA with a hospital-based diagnosis of rheumatic disease between 1980 and 2015. Notably, the registry comprises private and public hospital data but excludes data relating to primary care physicians or pharmaceutical prescriptions. All data in WARDER is coded using the period-relevant version of the International Classification of Diseases (ICD).

Among 18,473 RA patients registered in WARDER, we selected patients with two or more ICD codes for RA using a pre-determined

algorithm reviewed by the WA Department of Health Clinical Coding group (Table 1). The selection of patients with two or more RA codes ensured a high degree of sensitivity and specificity [17], and did not change the sociodemographic characteristics of the study population (Table S1). Subsequently, 9532 RA patients were identified. Of these patients, 1891 (20.6%) undergoing THR were identified by relevant ICD codes (Table 1). We then excluded patients who had undergone THR before first RA record ($n = 331$, 3.5%). Information extracted from the remaining 9201 RA patients (1560 undergoing THR) included age at first hospital contact for RA, sex, date of THR, and adjusted Charlson Comorbidity Index (CCI) at first RA contact and at THR. The adjusted CCI is a modification of the well-validated CCI, where higher scores indicate more comorbidities and are associated with worse survival irrespective of diagnosis [18]. Since all patients in this cohort study had RA, and we were interested in how comorbidities, not RA, affected outcomes. We used an adjusted score that removed the rheumatic components of the CCI (a maximum of 1 point was deducted from the score) [18–20]. Using this data, we estimated survival to mortality (from first RA record) and rates of, and time to adverse outcome of revision, peri-prosthetic fracture, infection, VTE, and mechanical loosening using further ICD codes (Table 1).

Ethics approval for this project was obtained from the Human Research Ethics Committee at the WA Department of Health (HREC 2016.24).

Statistical methods

Complication rates and incidence rates were compared using the Pearson’s Chi-square test. Mann–Whitney U test was used for pairwise comparison of continuous variables (gender, age, CCI). For statistical analysis of rates, patients were categorized into age groups (< 50, 50–65, 65–80, and 80 + years), year of first RA record (5-year periods from 1980 to 2015), and year of THR (5-year periods from 1980–2015). Incidence rates (IR) were calculated by dividing the number of THR in each time period by the total number of PY contributed by at risk

Table 1 ICD codes used for each concept, backward and forward mapped into the various versions of ICD codes used during our study 1980–2015

Concept	ICD 10	ICD 9 (used 1/1/1988–30/6/1999)	ICD 9 (used prior to 31/12/1987)
Hip replacement	49,318–00	81.51	58.15
	49,319–00	V43.64	V43.6
	Z96.64		
Revision	49,312–00	80.95	58.16
	49,324–00	80.05	
	49,327–00	81.53	
	49,330–00		
	49,333–00		
	49,339–00		
	49,342–00		
Dislocation	49,345–00		
	T84.0	996.4	996.4
	47,048–00	79.75	82.09
	47,051–00	79.85	57.96
Loosening Periprosthetic fracture	T84.0	996.4	
	M96.6	996.78	
		996.7	
	47,498–00	78.55	57.87
	47,501–00	78.59	57.9
	47,525–00	79.05	57.91
	47,525–01	79.15	57.92
	47,528–00	79.25	57.93
	47,528–01	79.35	57.94
	47,531–00	79.39	82.04
	47,534–00	79.45	
	47,537–00	79.55	
	47,516–01		
47,519–00			
Infection	T84.5	996.66	996.6

Table 1 continued

Concept	ICD 10	ICD 9 (used 1/1/ 1988–30/6/ 1999)	ICD 9 (used prior to 31/12/ 1987)
VTE	T84.8	996.77	996.7
	T84.82	996.78	

patients (in that time period) and presented per 1000 PY. At risk was defined as having an RA code recorded in the time period of interest or prior, and not having received THR or died. Significant differences in IR were tested for the overall study (where the expected rates derived from the 1980s group) and between incremental periods (where the predicted rate is derived from the previous time period). *P* values less than 0.05 were interpreted as indicating a significant change in IR had occurred. THR-free survival for the entire RA cohort was calculated as the time (in days) from the first recorded RA diagnostic code to the end of study (2015) or patient death date, with the first THR code as the event of interest. Patient survival after THR was calculated as the time from THR to the end of study or patient death, while AO-free survival times was calculated as the time from THR to the end of study or patient death, with AO as the event of interest. The frequency of each adverse outcome was also calculated, with events censored at the maximum follow-up times of 6 months, 5, 10, and 15 years post-THR. However, VTE was only followed to 6 months, as longer time periods were deemed unlikely to be related to THR [21]. Maximum follow-up times were selected to allow an examination of both short- and long-term complication rates [5, 22–26].

Survival rates were calculated using Kaplan–Meier life survival tables and compared using the log-rank Mantel–Cox test. Hazard ratios (HR) were estimated using Cox regression analysis. In Cox regression models, the covariates of age at first contact, age at THR, sex, CCI, year of RA diagnosis, and year of THR were adjusted. This analysis was conducted using Statistical Package for the Social Sciences

software (IBM SPSS Statistics for Windows, Version 27, IBM Corp., Armonk, NY, USA), with additional analysis in Microsoft Excel 2019 (Microsoft, Richmond WA, USA).

RESULTS

Demographics

There were proportionally more females in the THR cohort compared to the non-THR patients (7.9%, $p < 0.001$) (Table 2 and S2) but age at first RA contact did not differ significantly between THR vs. non-THR patients ($p > 0.2$). Age at first hospital contact decreased in the cohort of patients later requiring THR from 63.6 years to 55.1 years ($p < 0.001$), but not for the full RA cohort (mean age 59.4, $p > 0.1$) (Table 2). Women had a lower CCI at first RA hospital contact than men ($p < 0.01$) and THR patients had lower CCI scores than non-THR patients at first RA contact ($p < 0.001$) (Table S1). CCI scores at time of THR did not change significantly throughout the study ($p > 0.9$) (Table 2 and Table S2).

Total hip replacement-free and patient survival

In the full RA cohort, THR-free survival increased throughout the study (5-year survival increased from 84.3% to 95.3%) (Table 3). Risk factors for progressing to THR were increasing age at first RA contact and female sex (HR > 1.2 , $p < 0.001$), while later study entry and higher CCI at first RA contact reduced risk of THR (HR < 0.90 , $p < 0.001$) (Table 4). After controlling for age at RA diagnosis, CCI at RA diagnosis, and sex, progressing to THR did not significantly influence mortality rates in RA patients ($p = 0.5$, HR = 1.03) (Table S3 and S4). Patient survival was influenced by CCI ($p < 0.001$, HR 1.05) and age at first RA contact ($p < 0.001$, HR 2.27) (Table S4).

Table 2 Demographics of full RA cohort and THR-only cohort. Numbers for age and CCI reflect mean values with 95% confidence intervals

	1980–1985		1985–1990		1990–1995		1995–2000	
	Full cohort	THR-only cohort	Full cohort	THR-only cohort	Full cohort	THR-only cohort	Full cohort	THR-only cohort
<i>n</i> , % female	1982, 71.1	244, 75	1483, 67.4	223, 71.3	1360, 66.8	252, 79	1699, 70.4	295, 73.2
CCI at first RA contact	0.6, 0.5–0.6	1, 0.7–1.2	0.7, 0.7–0.8	0.8, 0.5–1	0.9, 0.9–1	0.8, 0.6–1	1.3, 1.2–1.4	0.7, 0.5–0.9
age at first RA contact	61.5, 60.8–62.2	63.6, 61.9–65.3	59.8, 58.8–60.7	64, 62.2–65.9	58.9, 57.9–60	62, 60.2–63.9	61.1, 60.1–62	63.6, 61.7–65.5
age at THR,	-	65, 63.3–66.7, 16.6	-	67.3, 65.5–69.1, 14.3	-	67.4, 65.7–69.1, 16.1	-	69.4, 67.7–71.2, 19.9
CCI at THR,	-	1.1, 0.8–1.4	-	0.8, 0.6–1.1	-	0.9, 0.6–1.2	-	0.9, 0.6–1.1
Total								
	2000–2005		2005–2010		2010–2015		Total	
	Full cohort	THR-only cohort	Full cohort	THR-only cohort	Full cohort	THR-only cohort	Full cohort	THR-only cohort
<i>n</i> , % female	953, 70.2	197, 80.2	1048, 65.6	189, 73.5	676, 69.5	160, 76.9	9201, 68.9	1560, 75.4
CCI at first RA contact	1.3, 1.2–1.5	0.7, 0.5–0.9	1.4, 1.3–1.5	0.7, 0.5–0.9	1.9, 1.7–2.1	0.6, 0.4–0.9	1.1, 1–1.1	0.8, 0.7–0.8
age at first RA contact	57.1, 55.6–58.5	59.4, 57–61.7	55.7, 54.3–57.2	56.3, 54–58.7	57.6, 55.7–59.4	55.1, 52.4–57.9	59.4, 58.9–59.8	61.1, 60.3–61.9
age at THR,	-	66.8, 64.6–69, 21.1	-	67.6, 65.6–69.7, 18.6	-	68, 65.6–70.5, 16.9	-	67.4, 66.7–68.1
CCI at THR,	-	0.9, 0.6–1.2	-	0.8, 0.5–1.1	-	0.7, 0.4–1	-	0.9, 0.8–1

n number of participants, % female proportion of patients in the cohort who were female, 95% CI 95% confidence interval, CCI Charlson Comorbidity Index

Table 3 Incidence rates of THR and THR-free survival measured from first RA contact by age and gender over time

THR IR and survival	1980–1985	1985–1990	1990–1995	1995–2000	2000–2005	2005–2010	2010–2015	Totals
THR number	244	223	252	295	197	189	160	1560
THR IR, 95% CI	46.8, 44.7–49.1*	20.8, 20.1–21.5	17.7, 17.2–18.2	16.1, 15.7–16.4	9.8, 9.6–10	9, 8.8–9.2	7.3, 7.2–7.5	14, 13.6–14.3
THR IR for men, 95% CI	40, 36.7–43.8*	19.3, 18.2–20.6	11.7, 11.1–12.3	13.5, 13–14.1	6.2, 6–6.5	7.6, 7.3–7.9	5.3, 5.1–5.5	10.9, 10.5–11.4
THR IR for women, 95% CI	49.6, 47–52.5*	21.5, 20.6–22.4	20.5, 19.8–21.2	17.3, 16.8–17.8	11.4, 11.1–11.7	9.6, 9.4–9.8	8.3, 8.1–8.5	15.4, 14.9–15.8
PY contributing female PY	5217, 3691	10,714, 7406	14,232, 9697	18,359, 12,512	20,183, 13,900	21,064, 14,488	21,853, 14,878	111,625, 76,574
1-year THR-free survival, standard error	93.5, 0.6	95.9, 0.5	95.6, 0.6	95.8, 0.5	96.2, 0.6	97.2, 0.5	96.5, 0.7	95.6, 0.2
5-year THR-free survival, standard error	84.3, 0.8	90.6, 0.8	89.4, 0.9	90.7, 0.7	93.6, 0.8	93.2, 0.8	NA	89.9, 0.3
10-year THR-free survival, standard error	77.9, 1	84.4, 1	84.8, 1	86.4, 0.9	90.5, 1	NA	NA	84.9, 0.4
15-year THR-free survival, standard error	71.8, 1.1	79.9, 1.2	82.3, 1.1	83.3, 1	NA	NA	NA	80.8, 0.5
20-year THR-free survival, standard error	69.3, 1.2	77.2, 1.2	80.9, 1.2	NA	NA	NA	NA	78.2, 0.5

THR total hip replacement, IR incidence rates, PY person-years. NA indicates that calculation of survival rates was not possible due to the follow-up being less than the designated survival time. *IR estimated were deemed to be inconsistently high, and most likely the result of counting historical cases hence were not used in further analysis

Table 4 Covariates used in the Cox regression analysis for survival from first RA contact to THR

	Significance (<i>p</i> value)	HR	95% CI
Gender	< 0.001	1.370	1.22–1.54
Age at first RA contact	< 0.001	1.290	1.22–1.36
Year of first RA contact	< 0.001	0.848	0.82–0.88
CCI at first RA contact	< 0.001	0.904	0.87–0.94

HR hazard ratio; 95% CI 95% confidence interval, CCI Charlson Comorbidity Index

Trend in total hip replacement incidence

THR IR decreased significantly (*p* < 0.01), from 20.8/ 1000 PY (95% CI 20.1–21.5) in 1985–1990, to 7.3/1000PY (95% CI 7.2–7.5) in 2010–2015, with the greatest decrease seen from 1995–2000 to 2000–2005 (Fig. 1 and Table 3). Trends were similar in male and female patients, with a slightly higher THR IR in females (Fig. 1).

Adverse outcomes

At 5, 10, and 15 years post-THR, the only complications to decrease significantly throughout our study were periprosthetic fracture and loosening, decreasing by in excess of 35% (*p* < 0.05). Infection rates and dislocation did

not change significantly (*p* > 0.05). Table 5 and Figs. 2 and 3.

Five-year AO rates, for all outcomes combined, averaged 8.0%, decreasing from 13.1% to 2.5% from 1980 to 2010, respectively (*p* < 0.001) (Table 5). A similar trend was observed for adverse outcomes at 15 years post THR which decreased from 21.1% to 12.2% from 1985 to 2000 (*p* < 0.001) (Table 5).

Dislocation

Dislocation rates decreased over the duration of our study. Five-year dislocation rates averaged 6.09% and decreased from 7.8 to 3.7% (1980–2010, *p* = 0.08) (Table 5 and Fig. 2). Similarly, 15-year dislocation rates decreased from 20.9 to 14.6% (1980–2000, *p* = 0.054) (Table 5 and Fig. 3). The probability of dislocation-free survival reduced (*p* < 0.01) with a later year of undergoing THR (HR 1.18, 95% CI 1.05–1.34) Sex, CCI, and age were not significantly associated with dislocation in any model (*p* > 0.05) (Table S5).

Loosening

Loosening rates averaged 14.3% at 15 years of follow-up and decreased significantly from 20.5 to 12.2%, 1980–2000 (*p* < 0.01) (Table 5 and Fig. 3). A similar, but non-significant, decrease was observed at 5 and 10 years of follow-up. From Cox regression models, year of THR was the only variable associated with loosening-free survival. The subsequent year of THR conferred a reduced survival (HR 1.16, 95% CI 1.02–1.32);

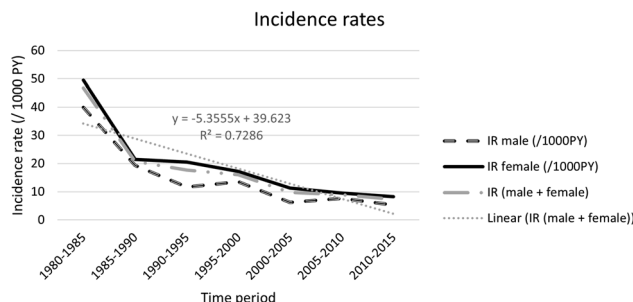


Fig. 1 THR incidence rates in RA patients by gender during 5-year intervals in study period 1980–2015

Table 5 Complication rates (given as % of total THR) at various maximum follow-up time points (6 months, 1 year, 5 years, 10 years, and 15 years)

	1980–1985		1985–1990		1990–1995		1995–2000		2000–2005		2005–2010		2010–2015		Totals																
	0.5	1	5	10	15	0.5	1	5	10	15	0.5	1	5	10	15	years															
Revision (%)	0	0	0.8	3.3	7.0	0.5	0.5	2.2	4.0	0.8	2.0	3.6	6.3	0.7	1.0	4.4	6.4	0.5	1.0	2.5	1.1	1.1	4.8	0.6	0.6	0.6	0.9	3.3	5.9	8.4	
Dislocation (%)	0.8	1.2	7.8	13.9	13.9	1.8	2.2	4.5	9.4	1.6	2.4	6.4	11.1	1.0	1.7	6.8	10.5	1.5	1.5	6.6	0.5	1.6	3.7	0.6	0.6	0.6	1.2	1.7	6.1	11.0	15.8
Loosening (%)	1.2	1.6	7.4	13.5	13.5	1.8	2.7	5.4	9.9	1.6	2.4	6.4	10.7	1.0	2.0	6.1	9.5	0	0.5	4.6	0	0.5	3.2	0.6	0.6	0.6	1.0	1.6	5.7	10.1	14.3
Fracture (%)	1.2	1.6	5.7	13.9	13.9	1.8	2.7	6.3	12.1	0	0.8	5.2	7.9	1.4	3.4	6.4	8.8	1.5	1.5	4.1	2.1	4.2	5.8	2.5	2.5	1.4	2.4	5.9	9.5	12.3	
Infection (%)	0	0.8	3.3	4.5	5.7	0	0.9	4.0	5.8	7.6	0.4	0.4	2.8	5.2	1.0	1.0	3.0	3.4	0.5	0.5	3.6	1.6	1.6	3.2	1.3	2.5	0.6	1.0	3.5	4.7	6.2
VTE (%)	0.4					0.5				0.0				0.0				1.5			0.5			0.0		0.4					
All AO (%)	1.6	3.3	13.1			2.7	4.5	10.8		1.6	3.2	11.1		2.0	3.1	7.5	9.2	1.5	1.5	3.1	2.7	3.2	3.7	2.5	2.5	2.1	3.1	8.0	12.6	16.4	
	24.2	33.2				16.6	21.1			15.9	21.0			12.2				7.6													

Note only the 0.5-year time period is displayed for VTE as longer time periods were not necessarily related to THR procedure or prosthesis. Abbreviations used include AO (adverse outcomes total), venous thromboembolism (VTE)

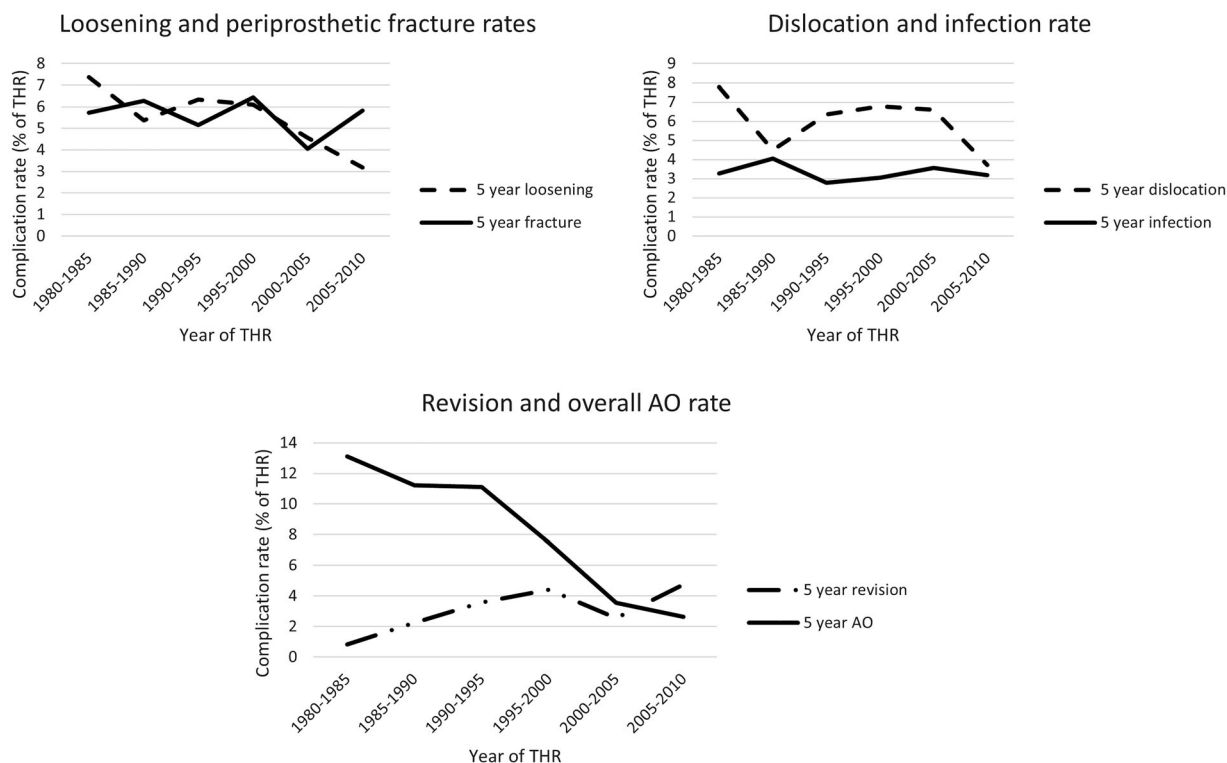


Fig. 2 Complication rates (as percentage of THR performed) at a maximum intervals of 5-year follow-up in study period 1980–2010

while sex, CCI, and age were not significantly associated with loosening ($p > 0.05$) (Table S5).

Revision

Revision rates at 5, 10, and 15 years did not decrease significantly over the duration of the study. 10-year revision rates increased from 3.3 to 7.1% (1980–2005); however, this was not significant ($p = 0.06$) (Table 5, Figs. 2, 3). The subsequent year of THR conferred a reduced survival rate (HR 1.34, 95% CI 1.17–1.62), while sex, CCI, and age were not significantly associated with this outcome ($p > 0.05$) (Table S5).

VTE

A total of eight VTE events were identified in the first 6 months post-THR (0.5%)(Table 5). Unfortunately, this meant there was an

insufficient number to carry out further analysis (stratification, survival, or trend over time).

Infection

Infection rates did not change significantly throughout our study ($p > 0.4$) (Table 5, Figs. 2, 3). Additionally, no variables were significantly associated with infection-free survival. (Table S5).

Periprosthetic fracture

Periprosthetic fracture rates decreased significantly, with 10-year fracture rates decreasing from 13.9 to 6.1% (1980–2005), $p = 0.007$ (Table 5, Fig. 3). Older patients at first RA contact had worse survival (HR 1.62, CI 1.33–2.30); while sex, year of THR, CCI, and age at THR did not prove significant associated with periprosthetic fracture rates ($p > 0.05$). (Table S5).

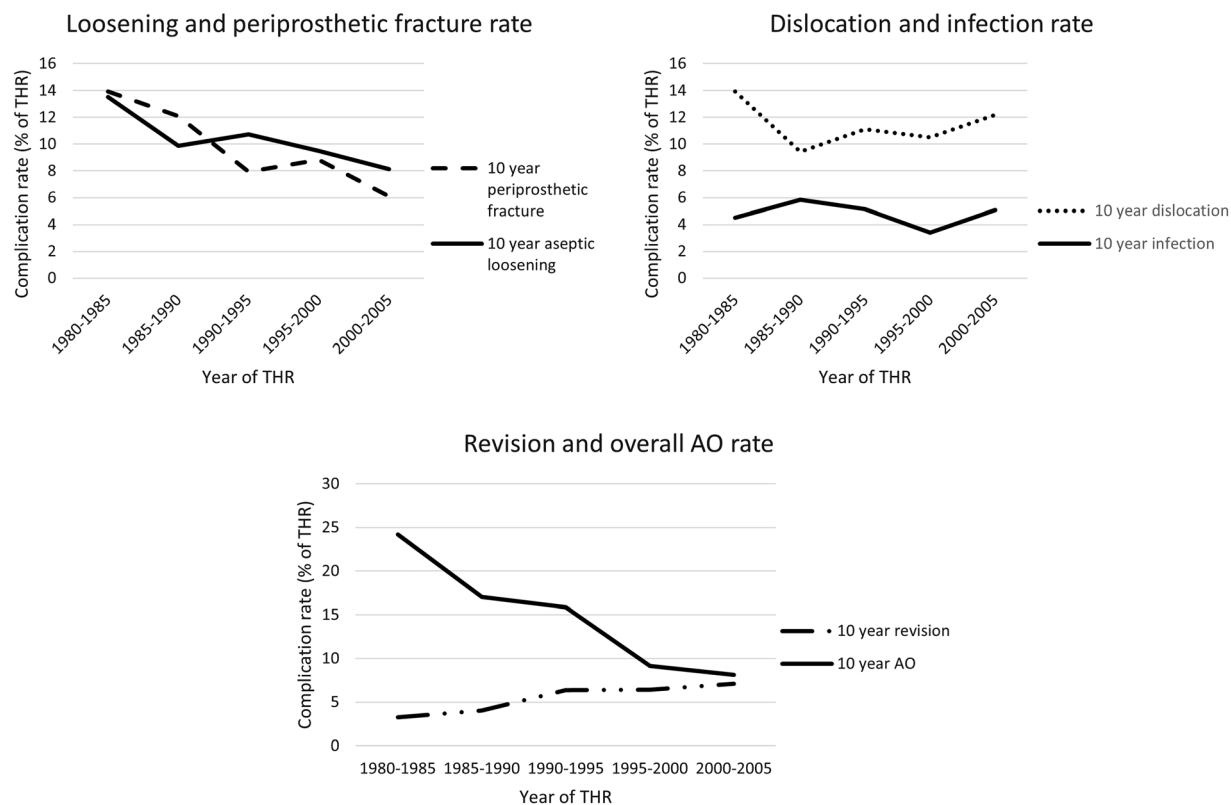


Fig. 3 Complication rates after maximum of 10-year follow-up in study period 1980–2005

DISCUSSION

We found that THR incidence for RA patients decreased over time, with the most significant change occurring around 2000 following a decade where Methotrexate therapy became anchored as first-line therapy for RA. The change in THR IR noted around 1985, is likely a result of the prevalent pool effect due to inclusion of patients with RA before 1980. RA patients progressing to THR encountered the hospital system at a younger age, had fewer comorbidities, and were more often female. THR did not influence patient survival, post-operative rates of periprosthetic fracture, and loosening decreased, but dislocation, infection, and revision rates did not change significantly over time.

THR IR for RA patients decreased significantly, which is in clear contrast to the THR IR for osteoarthritis (OA) patients and the general

population which continues to increase (approximately 50/100,000 patients in 1994 to 133/100,000 patients in 2017, in the Australian general population) [27–33]. The opposing trends for THR in RA and OA populations suggest an RA-specific cause for the reduction in THR IR, as opposed to a general reduction in THR rates (for OA and RA), which would have suggested a less RA-specific cause such as fewer THR being available. The role of RA management is further supported by our finding that later years of entry to the RA cohort reduced the HR for THR, consistent with other studies [8]. With RA and OA patients now undergoing THR at similar ages (65–69 years old), it would appear RA disease management has been successful in reducing RA joint destructive potential [27, 32, 34, 35].

THR IR reduced significantly from 1995–2000 to 2000–2005, which is just prior to the widespread use of bDMARDs, in a period

where increased use of csDMARD and shortening time to treatment occurred in the decade prior [36–41]. We found further support for the importance of early, aggressive antirheumatic therapy, as older patients at their first hospital contact for RA were at a higher risk of THR. If patients have an approximately constant age of onset, this elevated risk of THR in older patients could suggest a higher accumulation of joint damage due to slower time to treatment and worse RA control before THR. Alternatively, this could be the consequence of reasonable RA disease control in the community resulting in patients coming in contact with the hospital system, at older ages, due to age-related OA degeneration of the hip, as opposed to RA destruction. A further explanation for the significant decrease in THR IR around 2000 is a change from ICD9 to ICD10 coding in 1999.

An alternative explanation for reducing THR IR could be that fewer RA patients are deemed medically fit for surgery. One way of assessing medical fitness is via the CCI score [42]. In our study, patients with a higher CCI at first RA contact were less likely to receive a THR, suggesting there may be an element of surgical selection for more medically fit patients. Potentially due to surgical selection, the CCI at first RA contact for the THR cohort has remained unchanged, while the CCI at first RA contact for the entire RA cohort has continued to increase. Other studies have suggested THR is protective against mortality due to surgical selection identifying healthier patients [43]. However, after controlling for age at RA index date, CCI at first RA contact, and sex, our survival analysis suggests THR does not influence mortality rates in RA patients ($p > 0.05$). Survival was only reduced in patients with higher CCI and older age at RA diagnosis.

In summary, decreasing THR IR appear to be the result of a RA-specific factors coincide with the introduction of csDMARDs and the concept of the window of therapeutic opportunity, and occurred before the mainstream introduction of bDMARD.

THR complications

RA patients undergoing THR now have good postoperative outcomes, comparable to OA patients, with 1- and 5-year complication rates averaging under 3% and 8%, respectively [44, 45]. Declining 5-year postoperative complication rates from 8% to under 4% suggest a general improvement in the management of RA THR patients. Possible explanations for decreasing complication rates include increasing surgical THR volume in the general population, changes to surgical technique, and surgical selection of fitter patients [28, 46–48]. We found higher CCI increases HR for THR, THR patients have lower CCI (vs. non-THR), and CCI in THR patients has remained constant. This may suggest that surgical selection has prevented increasing complication rates, but has not resulted in decreasing rates of adverse outcomes.

Rates for individual complications did not decline equally. Mechanical complications potentially associated with the underlying RA disease activity (loosening and periprosthetic fracture) changed most significantly [35, 49–51], as opposed to infection, a non-mechanical complications.

Infection rates in this study are consistent with international and Australian rates for OA and RA populations and have not changed significantly over time [8, 52, 53]. This could suggest new infection control protocols have not affected postoperative complication rates to a large extent. Alternatively, changes to RA management, such as the increased use of DMARDs and bDMARDs, may have offset improvements resulting from modifications to infection control protocols [54–57]. However, the fact that infection rates are similar compared to the Australian OA and general population undergoing THR provides reassurance that the current use of antirheumatic drugs, does not place RA patients at an elevated risk of postoperative infection.

Complications potentially related to the underlying RA pathology and its management (such as corticosteroids), including aseptic loosening and periprosthetic fracture, have decreased over time in line with other studies

[35, 49–51]. We note periprosthetic fracture rates found in this study, contrast against the trend observed in OA patients, potentially suggesting improvements in RA disease management have at least partially improved post-operative outcomes [58–61]. While various studies report significantly different rates of periprosthetic fracture, due to population heterogeneity, it appears periprosthetic fracture rates are increasing [23, 62–64]. Lindahl et al. in a Swedish registry study from 1979–2000 found a nearly threefold increase in incidence from 0.045% to 0.13% [63], while Miettinen et al. found a similar threefold increase from 1.6 / 1000 PY to 4.5 / 1000 PY [65]. Furthermore, aseptic loosening rates appear to have decreased faster in RA patients, with RA and OA patients now having comparable loosening rates at 8% [66–71]. However, as these comparisons are made with similar studies and not directly with a comparative OA cohort, and a significant number of advances have occurred surrounding THR surgery, alternative explanations must be considered. Potential alternative explanations for the demonstrated improvements in post-operative outcomes include changes to prosthesis materials, patient optimization, surgical approach, and post-operative rehabilitation [51, 72–74].

Revision rates were low, under 1% at 1 year and 4% at 5 years, which is consistent with international rates [8] and remained constant across the duration of our study, suggesting that there has been improvement in treating other complications but not in preventing complications progressing to revision. Specifically, it appears that the increasing use of cementless fixation and newer prosthesis designs have not improved revision rates [52]. However, OA patients in the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) have better prosthesis survival rates compared to RA [35]. Hence, it appears that there is still room for improvement regarding the surgical management of RA patients.

Strengths and limitations

This large population-based RA cohort, with detailed demographic data, allowed us to consider whether the global changes in RA management, over time have improved severe disease outcomes in a non-selected population with statistical precision and high external validity. The long follow-up time allowed us to analyze changes to late complication rates, not able to be examined in many other studies. Lastly, the fact that diagnostic and procedural codes, which are based on a physician's diagnosis and transcribed by trained clinical coders, have been verified in previous studies [75], provides strong reassurance to the accuracy of codes used in this study.

Limitations result from the reliance solely on hospital-based administrative data and lack of a comparator group. The use of hospital-based administrative health data means more detailed clinical data, such as imaging, laboratory data, and pharmacological therapy were unavailable. With regards to the lack of a comparable OA cohort, we have tried as much as possible to make comparisons with studies and registries published within the region to minimize the effect of regional variations on our conclusions. A further limitation is the potential prevalent pool risk in the early years of study where prevalent cases of THR might have been incorrectly identified as incident cases, but we reduced this risk by using a 5-year wash-out period from 1980 to 1984. Regarding the use of the ICD code, each revision of the ICD system results in imperfect backward mapping; hence complication rates, particularly in the early years of study, are based on less detailed coding.

CONCLUSIONS

RA patients have become much less likely to require a THR and overall experience better postoperative outcomes. This likely results from the global trend of earlier and more effective antirheumatic drug therapy resulting in better disease control and lower the risk of joint damage. Whether the introduction of bDMARD therapy leads to further improvements in THR

incidence and outcomes will require further long-term study.

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Compliance with Ethical Guidelines. Ethics for this project was approved by the Human Research Ethics Committee at the WA Department of Health (HREC 2016.24). We confirm

that it was completed in accordance with the Helsinki Declaration of 1964.

Data Availability. All data generated or analyzed during this study are included in this published article/as supplementary information files.

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