International Registries – A Comparison of Outcomes

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37.1 Introduction

Along with the numerous successes of total knee arthroplasty (TKA), there have been many major failures during the course of implant development and our refinement in surgical technique (Maloney 2001). With the ever-increasing number of TKAs performed (Kurtz et al. 2007; Sloan et al. 2018; Losina et al. 2012) and the large financial cost to society, it is incumbent on the joint surgery community to track outcomes and treatment trends (Delaunay 2015). As orthopedic surgeons realized that it would be impossible for an individual surgeon to base his choice of optimal operative methods and/or implants on his/her own experience, it became apparent that aggregation of data was essential (Swedish Knee Arthroplasty Register 2018). However, examples set by early arthroplasty pioneers such as Charnley, Insall, and many others to insist on close, detailed follow-up and to develop systems for tracking their patients and documenting outcomes led to the early development of the large international registries we have today (Malchau et al. 2018). Here, we report on the outcomes of many large national registries as they pertain to TKA. We included those registries which deliver English language annual reports. We focus on outcomes based on indications and patient factors. We also report on some notable trends in care.

37.2 Registries

The purpose of a registry is to collect institutional, regional, or national data in order to analyze and draw statistically significant conclusions regarding patient, surgical technique, and implant-associated factors that lead to good or poor outcomes. The goal is to have enough data to allow adequate statistical analysis, mechanisms to track long-term results, assessment of quality, and recurring analysis to identify trends in care. With a significant cross section of the treatment community, registries possibly avoid performance bias, and reflect care provided in the wider community (Hughes et al. 2017). Registries also provide for post-market surveillance of implants, with numerous examples of registry-derived recalls (Furnes et al. 1997; Craviotto 2001). Additionally, registries also allow for the generation of scientific evidence, as well as assessment of large-scale cost-saving effects (Maloney 2001). Large clinical trials, which may answer some of these same questions, are independently time-consuming and costly for surgeons, groups, and health systems to perform.

37.2.1 History

The Mayo Clinic total joint registry is an institutionally based registry initiated by Dr. Mark Coventry in 1965 (Berry et al. 1997). This registry is commonly cited as being the first institutional arthroplasty registry (Delaunay 2015). The level of detail, including referencing radiographs and patient-reported outcome measures, allows a diversity and depth of study of questions that is different from, and complimentary to, large national registries. Because additional clinical information is archived, as compared to current national registries, institutional registries have the ability to identify the performance of specific implants in specific settings (Howard et al. 2011; Joglekar et al. 2012). William H. Harris, MD, DSc followed the Mayo Registry to create the second institutional joint registry in the United States at Mass General (Malchau et al. 2018). Similar to the Mayo, this registry began with the archiving of pre- and postoperative radiographs following the advent of digital radiography. Major contributions from this registry include evaluation of developments from the Harris Orthopedic Laboratory, including the creation and long-term follow-up of highly crosslinked polyethylene (Harris 1995). The first federally funded institutional hip and knee arthroplasty registry was created by David Schurman, MD at Stanford University in 1972.

Registries moved from an institutional and regional concept to one of analysis of a whole country's outcomes with the initiation of the Swedish Knee Arthroplasty Register in 1974 (Robertsson et al. 2000a; Knutson and Robertsson 2010). This allows for much larger patient numbers and more generalizable data secondary to the differences of practice settings represented (Herberts et al. 1989). It is estimated that this register currently captures 98% of all arthroplasty admissions in Sweden (Swedish Knee Arthroplasty Register 2018). Some early pioneering work from this registry includes risk factors and epidemiology of periprosthetic joint infection as well as early analysis of techniques or implants with high failure rates (Bengston et al. 1989; Knutson et al. 1981). These reports demonstrated the power of aggregated data of a national registry to the wider arthroplasty community.

❯ Following the Swedish example, multiple other national registries have been created (see overview of National Arthroplasty Registries below).

National Arthroplasty Registries – Developed between 1975–2007

- *Swedish Knee Arthroplasty Register*
  - Established in 1975
  - First National Total Knee Registry ever
  - >275,000 procedures
- *Swedish Hip Arthroplasty Register*
  - Established in 1979
  - First National Total Hip Registry ever
  - >450,000 procedures
- *Finnish National Arthroplasty Register*
  - Established in 1980
  - >400,000 procedures
- *Norwegian Arthroplasty Register*
  - Established in 1987
  - >200,000 procedures
- *Danish Hip Arthroplasty Register*
  - Established in 1995
  - >150,000 procedures
- *Danish Knee Arthroplasty Register*
  - Established in 1997
  - >100,000 procedures
- *New Zealand National Joint Register*
  - Established in 1998
  - >130,000 procedures
- *Australian National Joint Registry*
  - Established in 1999
  - >1,200,000 procedures
- *UK National Joint Registry*
  - Established in 2003
  - The world's largest joint registry
  - >2,350,000 procedures
- *Slovak National Arthroplasty Register*
  - Established in 2003
  - >40,000 procedures
- *Dutch Arthroplasty Register*
  - Established in 2007
  - >250,000 procedures

The majority of these registries have been established by professional societies (Swedish Knee Arthroplasty Register 2018; Finnish Arthroplasty Register 2017; American Joint Replacement Registry (AJRR) 2019) or as directed by national healthcare authorities (Canadian Institute for Health Information 2020; National Joint Registry 2018).

The Functional Outcomes Research for Comparative Effectiveness in Total Joint Replacement and Quality Improvement (FORCE-TJR) Registry was developed with the support from the Agency for Healthcare Quality and Research that was started in 2010 and was funded for 5 years (Franklin et al. 2013). This was one of the first attempts at a national American registry. The American Joint Replacement Registry (AJRR) followed the same year and was established by the American Academy of Orthopedic Surgeons (AAOS) to capture hip and knee arthroplasty data to conduct implant-specific survivorship analyses, produce risk-adjusted patient outcome data, and provide hospitals with quality benchmarks (Etkin and Springer 2017). The registry has rapidly spread throughout the United States, but is still capturing less than 50% of the nearly one million arthroplasties performed annually in the United States each year (AJRR report). With over two million hip and knee replacement procedures, it is currently the largest registry in the world based on procedure volume.

37.2.2 Collaboration

The International Society of Arthroplasty Registries (ISAR) was created in 2004 (▶ https://www.isarhome.org/). ISAR was established as a voluntary international organization with Professor Stephen Graves as inaugural president. Some of the goals of ISAR are to foster registry development, maintenance, cooperation, and the free reporting of outcomes. Encouraging uniformity of data collection in national registries allows for worldwide comparison of outcomes. Membership requires participation of over 80% of national hospitals and reporting of a minimum of 90% of procedures from each unit. Data collected must be validated. Associate members include registries with less than 80% coverage. There are currently 13 full-time members throughout the world (▶ https://www.isarhome.org/members). These include Australian, New Zealand, Romanian, UK NJR, Dutch, Danish, Swiss, Slovak, Swedish, Norwegian, Finish, and Lithuanian registries. The only US-based registry included as a full ISAR member is the Kaiser Permanente National Total Joint Registry (▶ https://national-implantregistries.kaiserpermanente.org/).

Further examples of international cooperation have been shown by the Nordic registries with the creation of The Nordic Arthroplasty Register Association (Havelin et al. 2009). This created a common Nordic database to compare results and further pool data.

37.2.3 Data Collected

International total joint replacement registries have traditionally focused on implant revision rates and tracked the length of time between the initial total joint replacement and implant removal. In this model, national registries incorporate large numbers of arthroplasties to identify device longevity. While the implant revision rate remains an important outcome, implant materials and technology have matured and patients and insurers want to understand the quality of care of the vast majority of patients who do not have a revision each year. Recently many registries have begun to add more data, including the capture and reporting on patient-reported outcome measures.

37.2.4 Weaknesses

> With all the success of national registries, there is a danger of using large observational data sets to make erroneous conclusions.

Correlations can be identified but causation cannot be concluded from these national registries (Lübbeke et al. 2017). Many types of bias can affect such associations including selection bias, performance bias, and in some cases, reporting bias. Interactions among variables may be difficult to tease apart. Risk stratification has often not been performed or may be rudimentary when reporting outcomes. Finally, as stated earlier, registries typically use revision as an endpoint and other outcome measures such as pain relief and function are equally as important to many patients.

37.3 Registries and Their Respective Sizes

The longest running national arthroplasty registry is the Swedish Joint Registry (Swedish Knee Arthroplasty Register 2018), which was started in 1974 as the Swedish Knee Arthroplasty Register and began reporting results in the early 1980s. Other international registries followed, including the Finnish (Finnish Arthroplasty Register 2017), Norwegian (Norwegian Arthroplasty Register 2019), Danish, New Zealand (New Zealand Orthopaedic Association 2018), Australian (Australian Orthopaedic Association National Joint Replacement Registry 2018), and UK Registries (National Joint Registry 2018) in that order. Other registries described in this chapter include the Canadian (Canadian Institute for Health Information 2020), Belgian (Orthopride Belgian Hip and Knee Arthroplasty Registry Annual Report 2018), Dutch (Dutch Arthroplasty Register (LROI) 2018), and the American Joint Replacement Registry (AJRR) (2019).

Registry basic information is included in Table 37.1. One of the largest databases is the National Joint Registry from the UK. The data in that registry spans 15 years (2003–2018), with the current total number of patients listed at 1,193,830. Over the most recent 3-year period they reported 274,495 procedures performed. This is secondary to the UK's large population size and capture rate. The AJRR's most recent report lists 828,999 total knee replacements captured over 6 years (2002–2018). With the large US population and number of procedures performed each year, it is likely that the AJRR will soon grow to be one of the largest national knee registries, even with a relatively low inclusion rate when compared to other national registries (Sloan et al. 2018). Another large database is the Australian registry with 658, 596 total knee patients. The Canadian Joint Replacement Registry (CJRR), which is relatively new, reported 202,319 total cases between 2012 and 2018, and likely will grow to be one of the larger registries as well. The Swedish registry, being the longest collecting TKA data (1974–2017), includes 270,159 patients. The most recent year lists 14,957 TKAs per-

Table 37.1 Registry sizes and reported participation

Registry	American	Australian	Belgian	Canadian	Dutch	Finnish	New Zealand	Norwegian	Swedish	UK/Wales
Years included	2012–2018	1999–2018	2009–2018	2012–2018	2010–2017	1980–2019	1999–2018	1994–2018	1974–2017	2003–2018
Participation	Unknown	95.9%	Est. 100%[a]	72.1%	>95% (+)	95.0%	>95.0%	97.1%	98.1%	95.2%
Registry case volumes										
TKA (No.)	828,999	782,600	–	202,319	220,499	230,529	110,678	97,022	270,159	1,193,830
Primary TKA in most recent year (No.)	139,582	56,259	25,915	70,502	32,258	12,679	8392	7567	14,957	105,278

TKA total knee arthroplasty

(+) van Steenbergen et al. (2015)

[a] Prosthesis reimbursement in Belgium is coupled to prosthesis entry into the registry as of September 1, 2015

formed. The majority of these databases demonstrated an increase in the number of cases performed over time.

Reported capture rates of patients in the included European registries range from approximately 95% in the Dutch, Finnish, and UK registries to 98.1% in the Swedish registry.

> ❯ Of note, the highest trajectory for capture comes from the Belgium registry where prosthesis reimbursement is dependent on its entry into the database as of September 1, 2015, resulting in an estimated 100% capture rate moving forward (Orthopride Belgian Hip and Knee Arthroplasty Registry Annual Report 2018).

The capture rate in North America is considerably lower, and given the impressive estimated annual procedural rates of total knee replacements in the United States ranging from 400,000 to −680,000 (Sloan et al. 2018; Losina et al. 2012; Singh et al. 2019) the AJRR current capture rate is approaching 50% of this annual volume in 2020.

Patient demographics can be seen in ▣ Table 37.2. The range of mean ages reported is 67–68.5 years. Age at which TKA prevalence peaks differs between the registries, with a high of 80–85 years old in the Swedish Registry to peaking in the 60–65 years old cohort in the AJRR. The majority of surgeries performed are on female patients. This is from a low of 51.8% of all patients in the New Zealand registry to 68.3% of patients in the Finnish registry.

ASA class is also commonly reported in these registries, with the majority of patients following into ASA II class (52–72%) depending on the registry. Body mass index (BMI) is reported in fewer than half of the included registries, although many intend on including these data moving forward. In the registries that include this data, only 10.6–17% are considered to fall into a healthy weight category with a BMI <25 while 31.1–69.4% of patients are classified as overweight with a BMI 25–30 and 16.1–56.1% of patients categorized as obese with BMI 30 or greater. The Dutch and Finnish registries are the only registries in which the majority of the patients have a BMI of <30 (58% and 83.95% of patients, respectively). The Australian registry included 58.3% of patients with a BMI >30.

Across registries, the majority of the surgeries included were for primary or idiopathic osteoarthritis (88–98.8%). The second and third most common diagnoses are post-traumatic arthritis and rheumatoid arthritis, respectively.

37.4 Outcomes Reporting

Reported outcomes in the registries vary but generally encompass the notion of cumulative revision rate or revision-free survival at multiple given time points reported by age, sex, fixation type, implant design, and by individual implants among other categories. Some registries include the measured revision rate as a portion of observed component years to standardize the differences in patient numbers seen at the various time points in follow-up (New Zealand Orthopaedic Association 2018). It has further been suggested that annual revision burden, the percentage of total cases that are revision arthroplasties, may also be a viable surrogate measure for comparative procedural success and quality improvement initiatives (American Joint Replacement Registry (AJRR) 2019).

■ Osteoarthritis

As a vast majority of cases in the registries are due to osteoarthritis as a primary cited etiology, it is, therefore, generalized that the overall reported results pertain to this diagnosis. When overall cumulative revision rates are reported by years of follow-up, they have been recorded here in 5-year increments (▣ Table 37.3). At the earliest time point of 5 years post-procedure, reported cumulative revision rate ranges from 2.0% to 3.5% while at the longest reported time points (18–20 years) revision rates vary from 5.5% in Belgium to 14.4% in Finnish males and 12.5% in Finnish females. Younger registries such as the Dutch LROI report outcomes at 5 and 9 years, respectively. Overall revision burden of the most recently reported year of the respective registry is also presented in ▣ Table 37.3. The Dutch registry reports the greatest revision burden of 9.4% while the Swedish registry claims the lowest revision burden of 5.2%.

> ❯ Pooled analysis of registries with greater than 15-year follow-up lists the 25-year survival of TKA at 82% (Evans et al. 2019).

■ Rheumatoid Arthritis

Outcomes for rheumatoid arthritis are discussed specifically in the Australian and Swedish registries. As a diagnosis, rheumatoid arthritis is responsible for as little as 1.3% of cases in Australia and as many as 4.9% of cases in Norway. The overall trend in etiologic burden is decreasing with improvements in the medical management for rheumatoid arthritis resulting in the prevention of articular erosion (Swedish Knee Arthroplasty

◘ **Table 37.2** Incidence of patient characteristics, fixation methods, and diagnoses by registry

Registry	American	Australian	Belgian	Canadian	Dutch	Finnish	New Zealand	Norwegian	Swedish	UK/Wales
Mean age										
Overall	67.0	68.5	67.6	–	68.6	–	–	68.5	68.9	69.0
Female	–	–	68.8	68.5	–	–	68.5	69.1	–	70.0
Male	–	–	68.1	68.1	–	–	67.9	67.5	–	69.0
Sex distribution										
Female (%)	61.1	56.6	61.3	61.3	64.0	68.3	51.6	62.5	56.0	56.7
Male (%)	38.9	43.4	38.7	38.7	36.0	31.7	48.4	37.5	44.0 (2017)	43.3
ASA class										
I (%)	–	6.0	–	–	12.0	8.0	11.0	14.6	–	11.9
II (%)	–	55.5	–	–	68.0	52.0	64.0	66.0	–	72.0
III (%)	–	37.4	–	–	20.0	39.9	24.0	19.3	–	15.8
IV (%)	–	1.1	–	–	–	–	1.0	0.1	–	0.3
BMI										
<25 (%)	–	10.6	–	–	17.0	14.5	11.3	–	–	–
25–30 (%)	–	31.1	–	–	41.0	69.4	32.7	–	–	–
30–40 (%)	–	47.7	–	–	38.0	16.1 (BMI >30)	46.7	–	–	–
>40 (%)	–	10.6	–	–	4.0	–	9.4	–	–	–
Diagnosis										
Osteoarthritis (%)	–	97.7	94.8	98.8	96.0	93.8	94.9	88[a]	>96[b]	97.4
Post-traumatic (%) (incl. ligament injury)	–	–	2.2	–	2.0	2.6	1.9	10.2[a]	<2[b]	–
Rheumatoid arthritis (%)	–	1.3	–	–	1.0	2.1	2.1	4.2[a]	<2[b]	–
Other inflammatory (%)	–	0.5	0.7	–	–	0.1	0.8	0.5[a]	–	–
Avascular necrosis (%)	–	0.3	1.3	–	1.0	0.5	0.3	0.2[a]	–	–
Neoplastic (%)	–	–	–	–	–	–	0.1	–	–	–

[a] Diagnoses are not mutually exclusive in the Norwegian registry

[b] Estimate from most recent time point in a line graph (1975–2017)

Register 2018; Australian Orthopaedic Association National Joint Replacement Registry 2018). Outcomes for rheumatoid arthritis appear non-contributory to implant survival. The Australian registry states that although the early revision rate (within 3 months) is higher in rheumatoid patients, by 9 months post-op the cumulative survival of the prosthesis is in fact better than their osteoarthritic cohort (◘ Fig. 37.1). Likewise, the Swedish registry showcases a survival curve in rheumatoid arthritis patients that demonstrates no significant difference compared to patients with osteoarthritis as a primary diagnosis at 10-year follow-up (◘ Fig. 37.2).

Table 37.3 Revision rate data by registry

Registry	American	Australian	Belgian		Cana-dian	Dutch	Finnish		New Zealand	Norwe-gian	Swedish	UK/ Wales
Revision burden												
7.5	8.7	8.0	6.9		9.4	6.9	7.5		8.6	5.2	6.0	
Cumulative revision rate												
At 5 yrs (%)	–	3.5	–		2.0	–	3.9 female 4.3 male		2.4	–	3.0[a]	2.7
At 10 yrs (%)	–	5.3	–		–	5.6 (9 yrs)	6.3 female 6.8 male		4.3	–	3.9[a]	4.4
At 15 yrs (%)	–	7.3	–		–	–	9.3 female 10.1 male		6.3	–	–	6.4
At 20 yrs (%)	–	8.6 (18 yrs)	5.5		–	–	12.5 female 14.4 male		7.9 (19 yrs)	10.5	7.0[b]	–
Revision rate by sex												
Time point	**–**	**18 yrs**	**–**		**–**	**9 yrs**	**10 yrs**	**25 yrs**	**Overall cohort**	**–**	**–**	**5 yrs**
Female (%)	–	7.9	–		–	5.8	6.3	15.9	3.1	–	–	6.0
Male (%)	–	9.5	–		–	5.5	6.8	17.9	3.6	–	–	6.3
Revision rate by age group												
Time point	–	**5 yrs**	**18 yrs**		–	–	**5 yrs**		**Overall cohort**	–	**5 yrs**	**5 yrs**
<55 yrs old (%)	–	6.6	17.8		–	–	5.0 female 6.5 male		6.7	–	4.0[a] (age <65)	4.4 female 5.0 male
55–64 yrs old (%)	–	4.5	11.7		–	–	2.9 female 3.8 male		4.4	–		2.8 female 3.3 male
65–74 yrs old (%)	–	3.3	7		–	–	1.9 female 2.7 male		2.9	–	2.7[a]	1.9 female 2.2 male
>75 yrs old (%)	–	2.2	3.6		–	–	1.7 female 2.1 male		1.6	–	2.5[a]	1.8 female 1.4 male
Time point	**3 months**	–	**5 yrs**	**10 yrs**	–	**9 yrs**	–		–	**5 yrs**	–	–

(continued)

Table 37.3 (continued)

Registry	American	Australian		Belgian		Canadian	Dutch	Finnish		New Zealand	Norwegian	Swedish	UK/Wales
<50 yrs old (%)	0.69	–		13^{b}	17.5^{b}	–	13.3	–		–	9.0 female 10.0 male	–	–
50–59 yrs old (%)	0.49	–		7^{b}	14^{b}	–	9.2	–		–		–	–
60–69 yrs old (%)	0.41	–		3.5^{b}	4.5^{b}	–	5.9	–		–		–	–
70–79 yrs old (%)	0.38	–		2.5^{b}	3^{b}	–	4.3	–		–	5.0 female 4.5 male	–	–
80–89 yrs old (%)	0.42	–		2^{b}	2^{b}	–	2.3 (age >80)	–		–		–	–
>89 yrs old (%)	0.49	–		(age >80)	–	–	–	–		–		–	–
Revision rate by fixation type													
Time point	**5 yrs**	**5 yrs**	**15 yrs**	–		–	–	**10 yrs**	**20 yrs**	**Overall cohort**	–	–	**15 yrs**
Cemented (%)	1.6^{b}	2.9 (MS) 3.9 (PS) 3.3 (MP)	6.5 (MS) 7.0 (PS) 6.8 (MP)	–		–	–	6.0	11.3	3.2	–	–	4.7
Uncemented (%)	2.1^{b}	4.2 (MS) 4.9 (PS) 5.8 (MP)	8.3 (MS) 7.0 (PS) 7.2 (MP)	–		–	–	12.8	27.1	5.2	–	–	6.2
Hybrid (%)	–	3.0 (MS) 5.4 (PS) 3.8 (MP)	6.5 (MS) 9.6 (PS)	–		–	–	–		4.5	–	–	4.4

Reasons for revision										
Aseptic loosening (%)	25	25	27.7	26.7	29.8	8.7	35.9	23.3	25[a]	27.5
Instability (%)	12.6	8.1	19.2	15.8	27.7	21.9	–	16.6	14[a]	16.5
Infection (%)	20.5	23.3	20.5	21.2	20.3	34.5	26.6	18.2	30[a]	25.4
Pain (%)	–	18	20.2	–	–	10.1	29.5	26.8	–	14.4
Other notable (%)	22.5 Other mechanical complications	–	11.8 Due to progressive OA	–	–	Non-exclusive diagnoses	Non-exclusive diagnoses	–	–	–

MS minimally stabilized (includes cruciate-retaining and ultra-congruent polyethylene prosthesis designs), *PS* posteriorly stabilized prostheses, *MP* medial pivot prosthesis

[a] Denotes estimate from 2007 to 2016 data set

[b] Denotes estimated of percentage from survival curve diagram

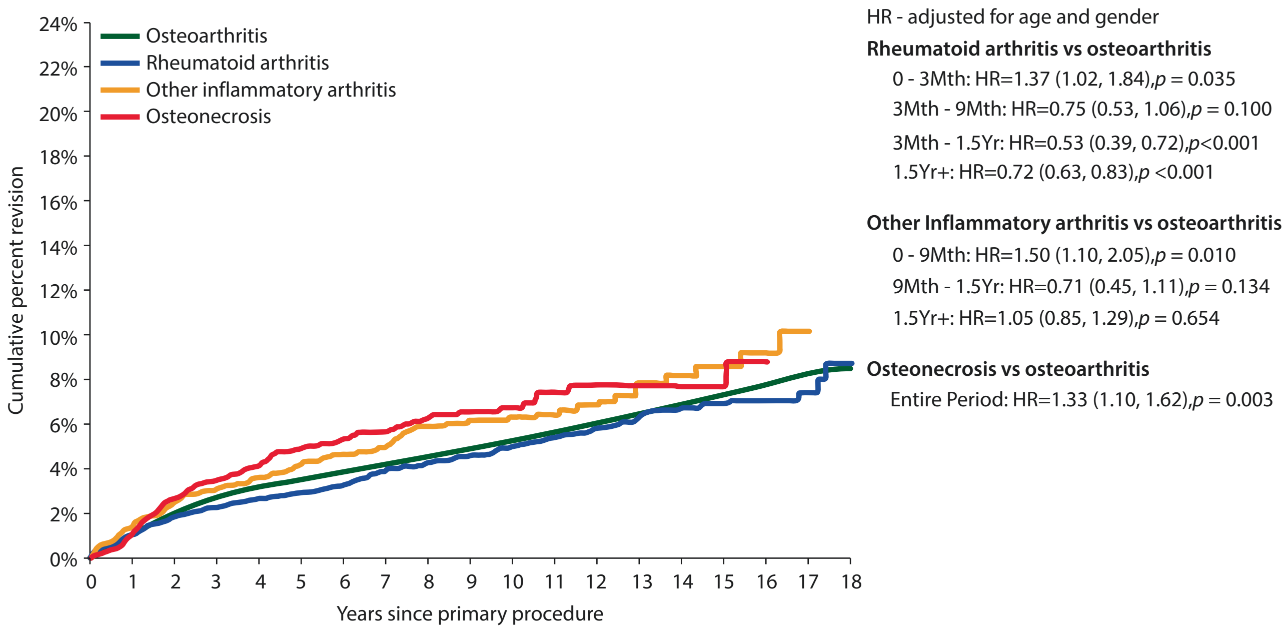


Fig. 37.1 Cumulative percent revision of primary total knee replacement by primary diagnosis

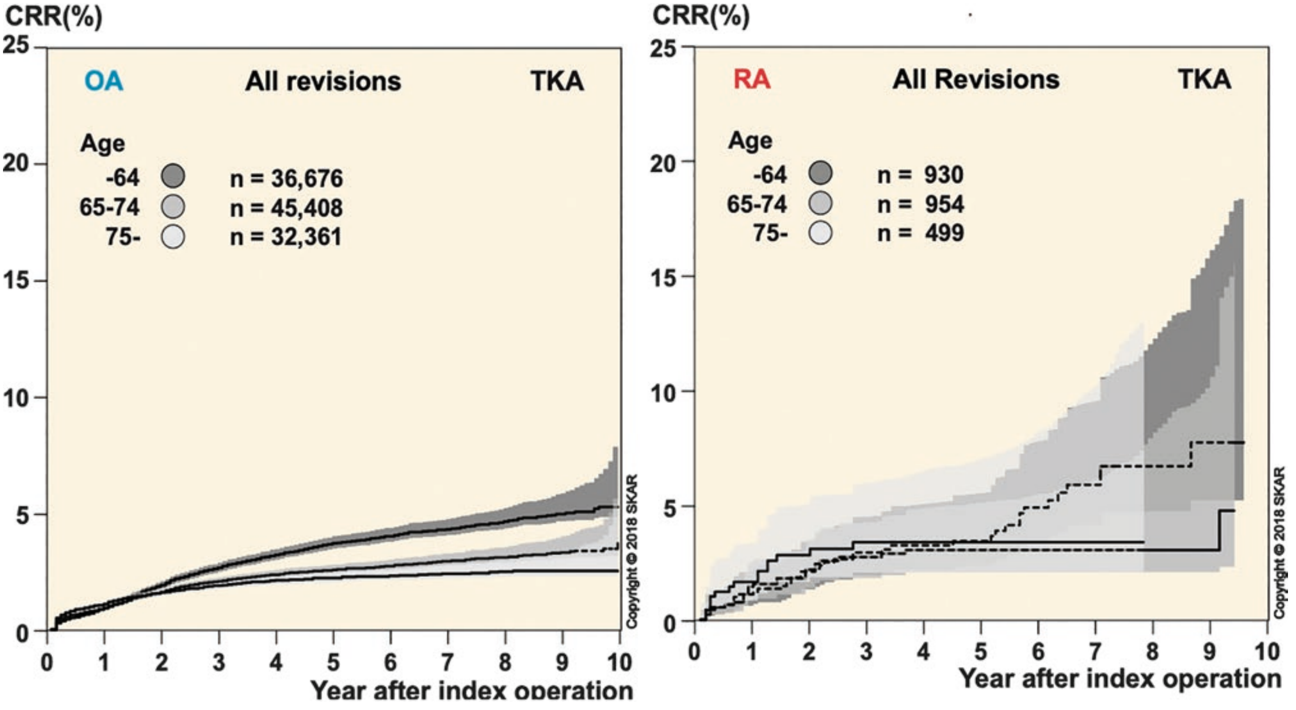


Fig. 37.2 Survival curve in rheumatoid arthritis (*RA*) patients compared to patients with osteoarthritis (*OA*) as a primary diagnosis at 10-year follow-up. *CRR* cumulative recurrence rate, *TKA* total knee arthroplasty (© Swedish Knee Arthroplasty Register [SKAR] 2018, with permission)

37.4.1 Outcomes Based on Patient Characteristics

37.4.1.1 Effect of Age

Assessment of implant survival based on patient age at the time of procedure is generally well-reported across registries (▣ Table 37.3). Reported age categories vary from commonly reported groupings such as <55, 55–64, 65–74, and 75+ years to groupings by decade of life. Timing varies from reports of early failure (within 3 months) reported in AJRR to 18-year data in the Australian registry and 20-year data in the Finnish registry, with most registries able to report outcomes at the 5-year mark. Some registries provided survival curve diagrams but not actual values, which require an estimation when extracting data. Consistent across all registries is a trend to lower revision rates with increasing age. In patients aged less than 55 years at the time of surgery the 5-year revision rates range from a low of 4.4% in female patients in the UK to a high of 9% in males in the Norwegian registry (in the age under 60 years category). At longer follow-up this age group sees the highest rates of revision documented at 17.8% at 18 years in the Australian registry and a remarkable 26.9% revision rate at 20 years in the Finnish registry. Revision rate in the 55–64-year age group at 5 years follow-up ranges from 2.8% in females in the UK to 4.8% in all sexes in the Finnish registry with long-term revision rates approaching 18.6%. The 65–74-year age group has documented revision rates at the 5-year time point ranging from 1.9% to 3.7% with long-range revision rates from 7% to 10.2%. The older age groups being 75 years or greater at the time of surgery have the lowest revision rates ranging from 1.4% to 5.0% at 5 years and comparatively very low revision rates at long-term follow-up, granted the longevity of the implant may outlast the remainder of the patients' years at this stage, with reported revision rates for those who survive to the 18- and 20-year time points of 3.6–5.0%, respectively.

> Younger age at implantation, specifically in males, has been shown to significantly increase revision rates, presumably from higher demand and heavier stress placed on the implants (Bayliss et al. 2017).

- **Effect of Sex**

Overall cumulative survival reported by sex was provided in 5 registries (▣ Table 37.3). The overall revision rate for males is higher than that for females in all registries other than the Dutch registry, albeit by never more than 2%. The Dutch registry reports revision rates of 5.8% and 5.5% for female and male patients, respectively, at 9-year follow-up. From the registries that report on sex differences in outcomes at multiple time points the difference between male and female revision rates becomes more apparent with time as the greatest differences are seen at final follow-up. The largest difference between the sexes at final follow-up is 2% seen in the Finnish registry at 25 years (revision rates of 15.9% for females and 17.9% for males) and in the UK registry at 15 years (15.5% for females and 17.5% for males). The Australian registry reports revision rates of 7.9% for females and 9.5% for males at 18-year follow-up. Patient-reported outcomes based on sex have not been currently reported. Previous studies have demonstrated worse postoperative patient-reported outcomes in females, but this may be secondary to worse preoperative function and pain (Barrack et al. 2014).

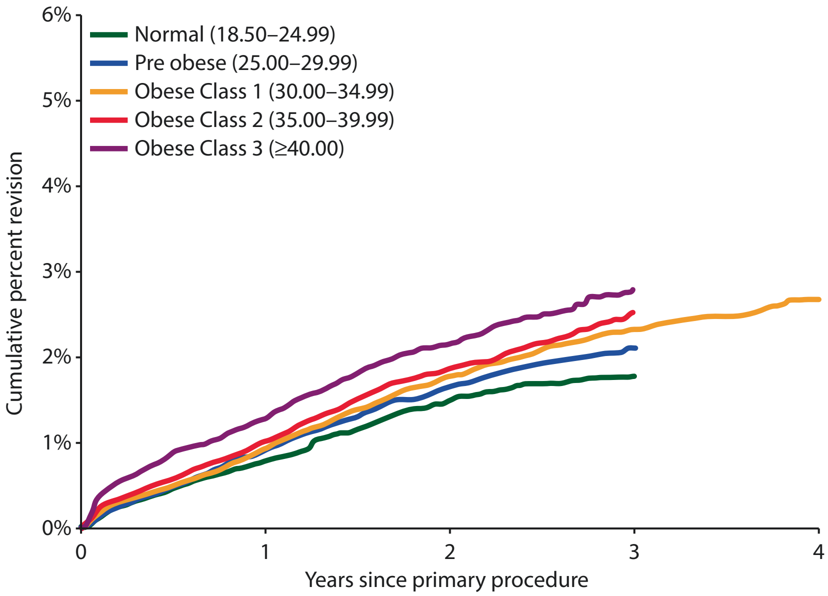
> However, as seen in this registry data, aggregation of large clinical studies has shown a trend toward higher revision rates in males following TKAs (O'Connor 2011).

- **Effect of BMI**

The effect of BMI is increasingly becoming a focus of registries moving forward; however, only the Australian and New Zealand registries have reported data available in their annual reports. Data on BMI has been collected since 2015 in the Australian registry. While no difference has been detected in revision rates between patients of normal weight and those classified as overweight or obesity class 1, early revision rates (within the first 6 months) are increased in patients in the obesity class 2 or greater categories (▣ Fig. 37.3).

> Of note, the Australian registry further showcases that BMI class experiences more revisions due to infection.

The New Zealand registry has collected BMI data since 2010 and reports revision rate of BMI categories by rate of revision per 100 component years. There have only been 89 revisions in patients with BMI <19 providing 331.6 observed component years with a reported observed rate of revision of 0.00 (95% CI 0.00–1.11). Patients with BMI 19–24 demonstrate a revision rate per 100 component years of 0.66 (95% CI 0.54–0.80), while patients within BMI ranges 25–29 and 30–39 have demonstrated rates of 0.57 (95% CI 0.50–0.64) and 0.59 (95% CI 0.53–0.65), respectively. Patients with BMI scores of 40 and higher demonstrate the highest rate of revision at 0.83 revisions per 100 component years (95% CI 0.26–1.08). The New Zealand registry also provides data on patient-reported outcomes by way of an Oxford knee score compared to BMI status at 5 years follow-up. Oxford knee scores range from a low of 36.11 seen in patients with BMI 40+ to a high of 39.81 seen with



HR - Adjusted for age and gender

Pre obese (25.00-29.99) vs normal (18.50-24 .99)
Entire period: HR = 1.03 (0.89, 1.18),$p = 0.698$

Obese Class 1 (30.00-34.99) vs
Normal (18.50-24.99)
Entire period: HR = 1.08 (0.94, 1.24),$p = 0.287$

Obese Class 2 (35.00-39.99) vs
normal (18.50-24.99)
Entire period: HR = 1.17 (1.01, 1.36),$p = 0.040$

Obese Class 3 (≥40.00) vs normal (18.50-24.99)
0 - 6Mth: HR = 1.87 (1.53, 2.39),$p<0.001$
6Mth+: HR = 1.08 (0.90, 1.30),$p = 0.405$

▣ **Fig. 37.3** Cumulative percent revision of primary total knee replacement by BMI category (primary diagnosis OA)

patients with a BMI 19–24. The outcomes of morbidly obese patients (>40 BMI), compared to simply obese patients, have shown to have worse outcomes in multiple other previous studies (George et al. 2018).

■ Effect of ASA Status

Data on outcomes based on ASA status are available in the Australian, Dutch, and New Zealand registries. The Australian registry has reported data on ASA status in 285,168 patients with up to 4 years follow-up for ASA class V patients, 5 years follow-up for ASA class I and IV patients, and 6 years follow-up for ASA class II and III patients. At these respective time points, revision rates are reported as

- 2.9% for class I,
- 3.2% for class II,
- 3.6% for class III,
- 4.4% for class IV, and
- 0% for the 16 patients registered in ASA class V.

In addition to cumulative revision rates, the Australian registry also provides a chart that highlights the reasons for revision within ASA classes I–IV which shows an increasing risk of infection in ASA class III and IV and potentially an increasing risk of loosening in ASA class IV, though exact values and confidence intervals are not provided (▣ Fig. 37.4).

The Dutch registry provides a cumulative revision graph on survival based on competing risk assessment by ASA class showing a small but significant increase in revision rates at 9 years for patients with ASA class I compared to all others with a rate of

- 6.2% (95% CI 5.9–6.5%) for ASA class I
- 5.2% (95% CI 5.0–5.4%) for class II
- 5.1% (95% CI 4.7–5.5%) for a combined cohort of ASA class III and IV patients (▣ Fig. 37.5)

However, in their Kaplan-Meier assessment, only the ASA class I and class II cohorts have non-overlapping 95% confidence intervals.

The New Zealand registry began collecting ASA classification data in 2005 and provides revision rates per 100 component years of

- 0.53 (95% CI 0.47–0.59) for ASA class I
- 0.48 (95% CI 0.48–0.51) for class II
- 0.56 (95% CI 0.52–0.60) for class III
- 0.57 (95% CI 0.26–1.08) for ASA class IV

37.4.2 Outcomes Based on Method of Fixation

Many registries report objective values for incidence of cemented, uncemented, and hybrid total knee arthroplasties (▣ Table 37.4).

> ❯ The most notable outlier is Australia as the only registry reporting rates of fully cemented total knee arthroplasty below 90% (68.6%).

Outcomes by fixation method are reported in the American, Australian, Finnish, New Zealand, and UK registries at various time points ranging from 5 to 20 years (▣ Table 37.3). The American registry provides a sur-

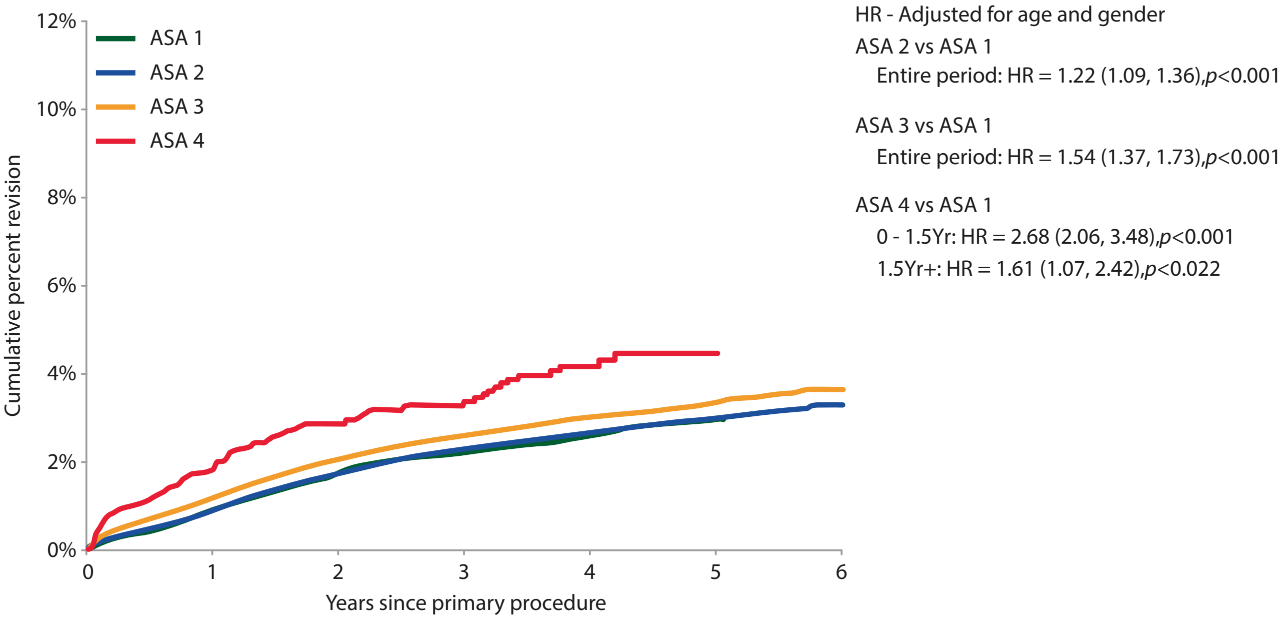


Fig. 37.4 Cumulative percent revision of primary total knee replacement by ASA score (primary diagnosis OA)

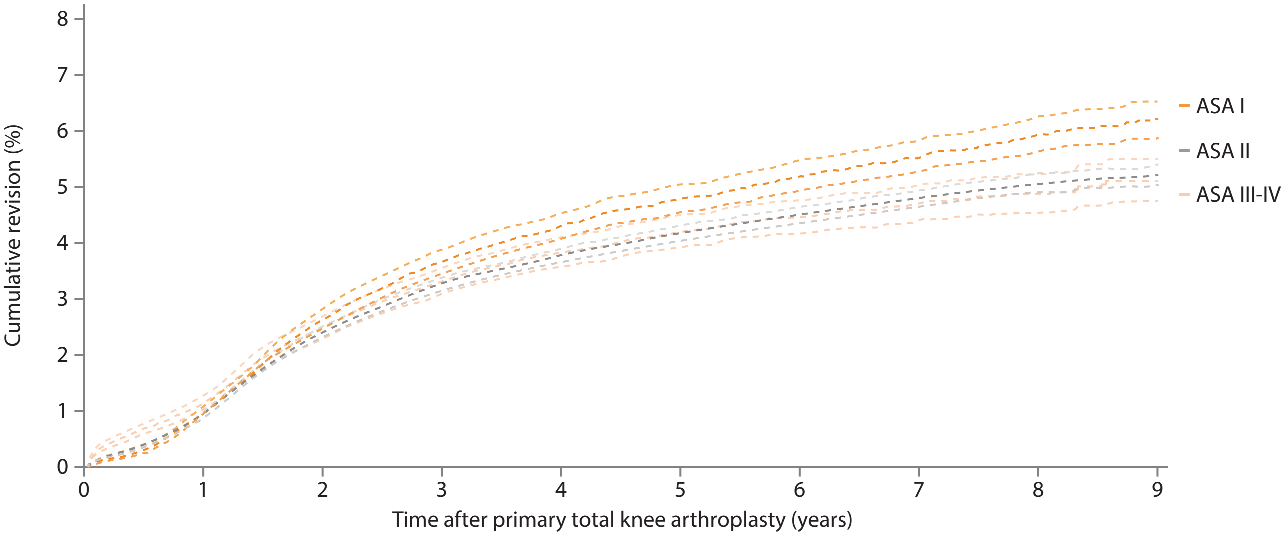


Fig. 37.5 Cumulative percent revision of primary total knee arthroplasties by ASA score in The Netherlands in 2007–2017 ($N = 206{,}162$). *Dotted lines* represent upper and lower limits of the 95% confidence interval (© Dutch Arthroplasty Register [LROI], with permission)

vival curve diagram which permits estimation of revision rate at 5 years of approximately 1.6% and 2.1% for cemented and uncemented/hybrid fixation methods, respectively. The Australian registry separates survival analysis by both fixation method and implant type. For minimally stabilized prostheses, uncemented fixation techniques are reported to have the highest cumulative revision rates while no difference is seen between cemented and hybrid cemented techniques. In posteriorly stabilized prostheses there is a time-dependent difference in survival based on technique with cemented fixation demonstrating lower revision rates for the first 2.5 years while after 4.5 years cementless fixation techniques demonstrate a lower revision rate, with hybrid fixation of posteriorly stabilized prostheses having the highest revision rate at all time points. When analyzing the medial pivot prosthesis design, the Australian registry demonstrates higher revision rates in cementless techniques compared to cemented techniques with no difference detected between either technique and hybrid fixation. The Finnish registry demonstrates a substantially higher cumulative revision rate in uncemented techniques which are double that of cemented at 10 years (6.0% cemented vs. 12.8% uncemented) with the gap

Table 37.4 Implantation technique, use of navigation and Rate of patellar resurfacing by registry

Registry	American	Australian	Belgian	Canadian	Dutch	Finnish	New Zealand	Norwegian	Swedish	UK/ Wales
Fixation method (TKA)										
Cemented (%)	93.8	68.6	91.1	–	93.2	93.5	92.0	–	92.6	94.9
Uncemented (%)	6.2	9.9	4.8	–	4.1	5.8	5.0	–	7.0	4.2
Hybrid (%)	–	21.5	3.9	–	2.7	0.7	3.0	–	0.1 (2017 data)	0.9
Use of navigation										
(%)	–	33.2	–	–	–	–	13.1[a]	–	–	–
Patellar resurfacing										
(%)	90.6	66.6	–	–	92.8	–	37.0	8.6	2.4	–

TKA total knee arthroplasty

[a] Includes approaches classified as image-guided and robot navigation

widening with time such that at 20 years follow-up cemented fixation results in a revision rate of 11.3% while uncemented fixation techniques display a 27.1% cumulative revision rate. Cementless fixation technique is associated with higher mean cumulative revision rates in the New Zealand and UK registries as well, to a lesser degree however (Table 37.3).

37.4.3 Reasons for Revision

All registries provided a method for reporting the reasons for revisions in TKA and at minimum the 3 most common reasons are reported in Table 3. The majority of registries list aseptic loosening as the number one cause of revision. An outlier in this area is the Finnish registry reporting a rate of revision for aseptic loosening of only 8.7% yet a rate of revision for infection of 34.5%. Whereas the New Zealand registry reports non-exclusive diagnoses with 35.9% of revisions carrying at least one diagnosis of a loose component. The Canadian and Swedish registries list infection as the number one reason for revision. In Norway, pain is the most commonly provided reason listed at the time of revision, although in the Norwegian database revision reasons are non-exclusive.

As some registries have all reported diagnostic reasons compiled such that rates are non-exclusive and total percentages add up to greater than 100%, the level of detail provided in revision cases varies considerably. Furthermore, it has been demonstrated that the most common causes of revision differ depending on if you look at acute vs. late causes (Sharkey et al. 2014) and this is not specified in the registries. Overall, in registries with exclusive diagnoses, the rate of instability ranges from 8.1% to 19.2%, rate of infection ranges from 18.2% to 34.5% and where reported the revision rate for a primary diagnosis of pain ranges from 10.1% to 26.8%.

Other notable reported reasons for revision include the Belgian registry reporting an 11.8% rate of revision due to progressive OA in unaddressed compartments and the American registry reporting 22.5% of revisions being performed for mechanical complications other than aseptic loosening and instability.

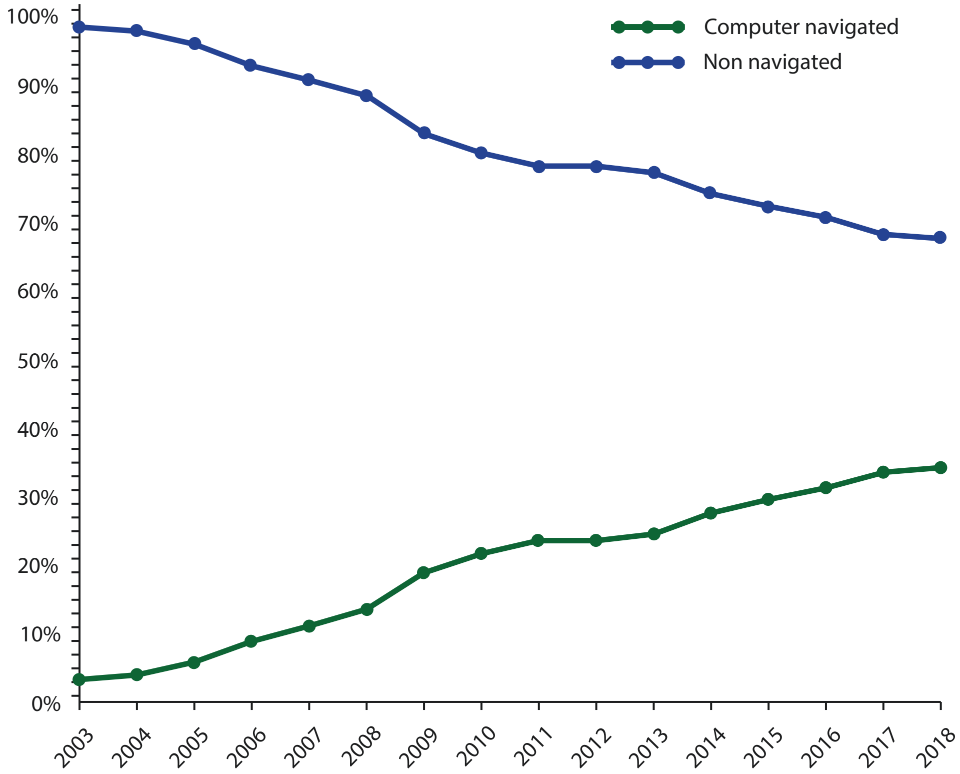
37.4.4 Notable Trends

Some trends have been shown in these international registries, one of which is the trend in number of cases performed yearly has increased in all the registries we included.

> This increase in TKA utilization cannot be explained by simply an increase in the population and may indicate expanded indications and patient demand (Losina et al. 2012).

The use of navigation has begun to be tracked by several registries and is now being reported on. Australia has reported an increase from 2.4% of TKA cases performed in 2003 using navigation to 33.2% in 2018 (Fig. 37.6). Some registries have begun to capture the use of robotics but currently this has not been reported in annual reports. In the Australian registry, patients aged <65 years have a

Fig. 37.6 Primary total knee replacement by computer navigation



lower rate of revision when computer navigation is used compared to when it is not used.

Resurfacing vs. non-resurfacing of the patella is also reported on and some notable trends can be seen. In the Australian registry the rate of patella resurfacing was as low as 41.5% in 2003 and has now increased to 69.1% in 2018 (Fig. 37.7). Norway has also demonstrated an increase in percentage of patella resurfacings, currently at 8.6% of TKAs from 2.2% in 2010. The Norwegian registry cited a report on their own data demonstrating higher KOOS scores in resurfaced TKAs as driving this trend (Aunan et al. 2016). The highest reported amount of patella resurfacing is seen in the AJRR at 90.6%. This is down from a high of 93.6% reported in 2012. The lowest reported percentage of resurfacing was reported in Sweden at 2.4%, which have been decreasing since the 1980s. Their recent high was 15% in 2005. In New Zealand 63% of the TKAs had no patella resurfacing, with 37% having a patella resurfaced.

The use of highly cross-linked polyethylene continues to increase. The use of highly cross-linked polyethylene has continued to increase from a low of 7.1% to 64.2% of TKAs in the Australian registry. The use of antioxidant polyethylene has increased from 2.5% in 2012 to 23.2% of TKAs in the current AJRR report. Unicondylar knee arthroplasty (UKA) use in the Swedish registry has decreased over time compared to TKA (Fig. 37.8) but has increased in utilization in the past 5 years.

In the Australian registry, the use of partial knee replacements has decreased from a high of 12.3% of all procedures to a 5.8% in 2018. The 2018 value is, however, slightly increased from a low of 4.2% in 2014. In the UK, NJR UKAs have remained relatively steady since they began recording data in 2003 with a rate around 10% of the procedures.

Norway has demonstrated a decreasing trend in the use of a surgical drain, from a high of 49% in 2011 to a low of 15% in 2018.

When examining the mean length of stay as reported to AJRR, there has been a significant decrease of 0.9 days for TKAs comparing 2012–2018. A significant decrease in mean length of stay for partial knee arthroplasties of 1.2 days was also seen.

37.4.5 Patient-Reported Outcome Measures

Traditional TJA registries were designed to collect data useful to monitoring implant survival and failure as defined by revision rates (Franklin et al. 2013). While the implant revision rate remains an important outcome, registries are currently utilizing patient-reported outcome measures (PROMs) to contextualize patient function prior to a revision.

Fig. 37.7 Primary total knee replacement by patella usage

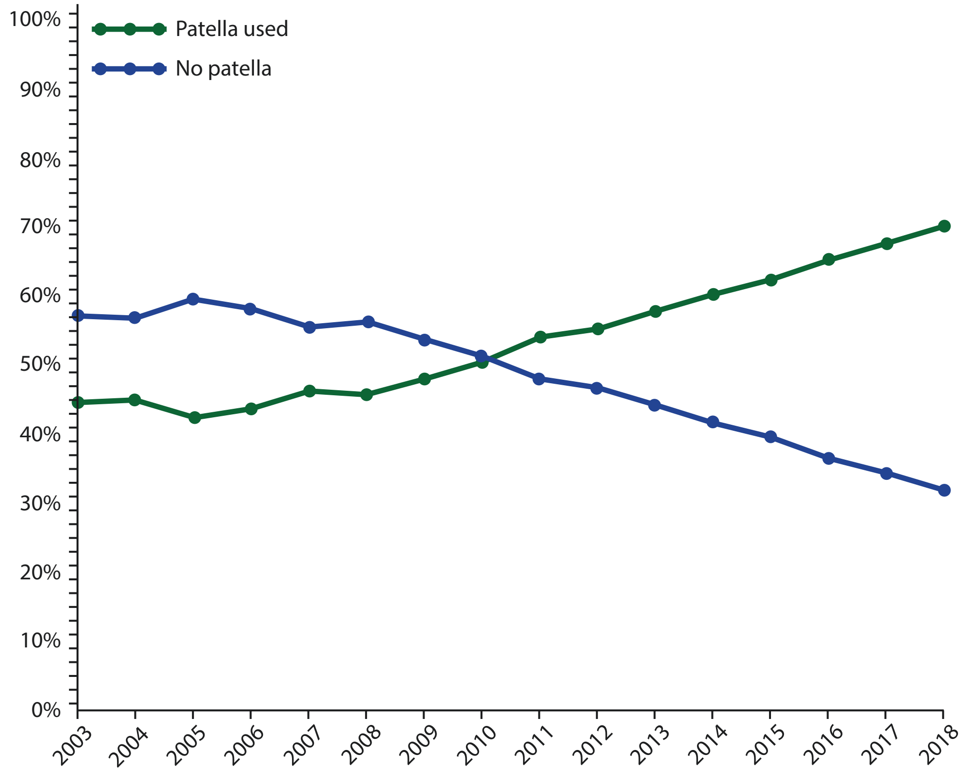
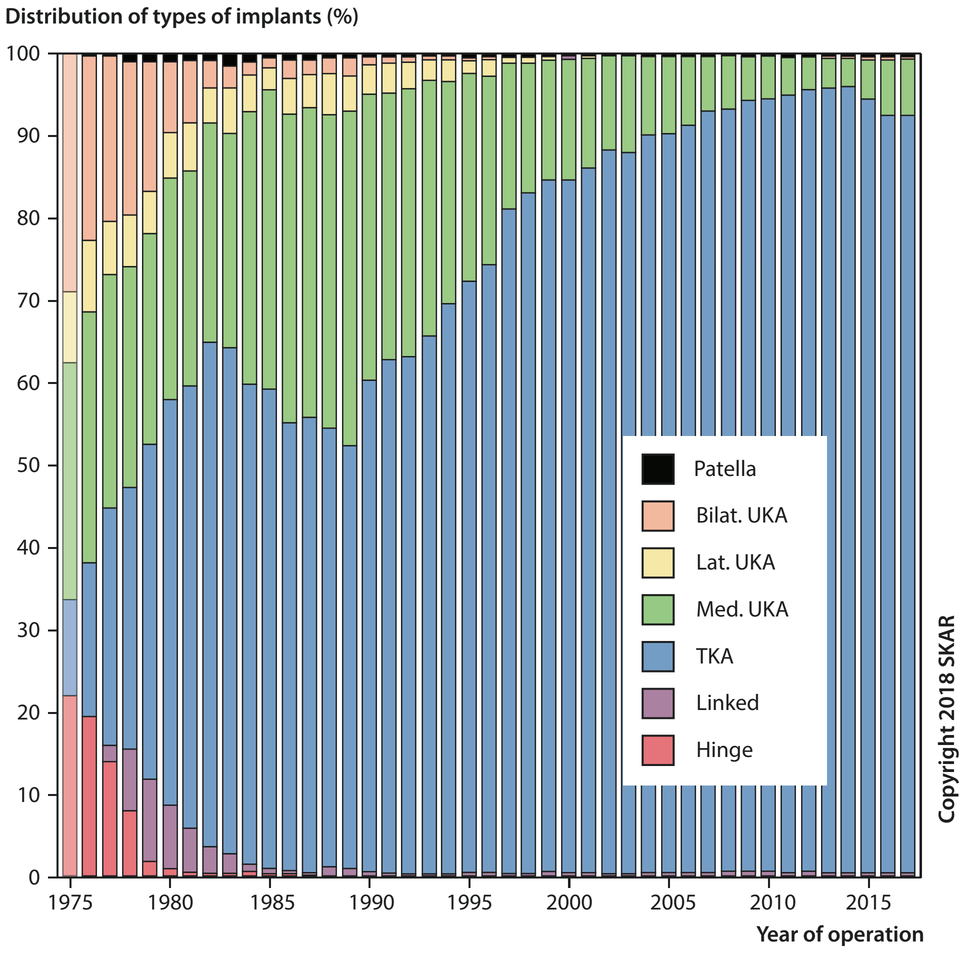


Fig. 37.8 Relative yearly distribution of implant types used for primary surgery (© Swedish Knee Arthroplasty Register [SKAR] 2018, with permission)



> Total joint arthroplasty is performed to decrease pain as well as to restore function and quality of life. It is, therefore, important to measure these same outcomes when assessing the registry results of TKA (Wilson et al. 2019).

Revision itself as an endpoint is rather straightforward, but it is likely insufficient as a measure of success given the fact that 1-year TKA survivorship is almost 100%, while only 80% of the patients are satisfied (Robertsson et al. 2000b). However, numerous barriers exist to the implementation of PROM collection for national registries including, but not limited to, cost, time, and response rate. Given this difficulty, ISAR PROMs Working Group proposes a 60% threshold for an acceptable frequency of collection based on these external difficulties in collection (ISAR Website 2020). The New Zealand registry was an early adopter of postoperative PROMs for hip and knee procedures, beginning at its inception in 1998. Other European registries followed with the Swedish hip registry in 2002, the UK NJR in 2009, and the Norwegian hip fracture registry in 2005 (Rolfson et al. 2011). The current national knee registries'annual reports that include PROMs include AJRR, Canada, Dutch, New Zealand, and Swedish Joint Registry (▣ Table 37.5). The UK NJR registry reports annual PROMs separately on the NHS website (NHS Digital 2020).

Not all registries collect the same PROMs, which differ in the type of data collected. The Canadian, Dutch, UK NKR, and New Zealand registries collect the Oxford knee score. The Canadian, Dutch, UK NJR Wales, and Swedish registries all collect the EQ-5D. The Swedish, Dutch, and American registries collect the knee injury and osteoarthritis outcome score (KOOS). AJRR also collects PROMIS and VR-12. The Dutch collect the numeric rating scale (NRS). The Swedish and UK NJR also collect the visual analog scale (VAS). The Swedish registry collects the OMERACT-OARSI.

> At this stage, the vast majority of these registries' PROMs are currently reported as overall outcomes from preoperative to postoperative and are not broken down into comparisons based on patient demographics, surgical techniques, or specific implants.

As an exception, the New Zealand joint registry has reported Oxford knee scores by BMI class at 6 months postoperatively in a cohort of 8663 patients.

Conclusion

Here, we reported on the current status of the international registries. We included national registries which report annual English language analyses. We attempted to give an overall picture of the status of the registries and the outcomes that can be learned from them. The quality of data obtained from these registries continues to improve, as the number of national registries and their capture rates has grown. As collaboration progresses as well, we will continue to learn more about our total knee arthroplasty outcomes from a global perspective.

Table 37.5 Patient-reported outcome details by registry

Registry	American	Australian	Belgian	Canadian	Dutch	Finnish	New Zealand	Norwegian	Swedish	UK/Wales
Patient-reported outcome measures										
Oxford knee	–	–	–	Oxford knee	Oxford knee	–	Oxford knee	–	–	Oxford knee
KOOS	KOOS JR	KOOS-12	–	–	KOOS PS	–	–	–	KOOS	
EQ-5D	–	–	–	EQ-5D-5L	EQ-5D index EQ-5D thermometer	–	–	–	EQ-5D	EQ-5D
PROMIS	PROMIS-10	–	–	–	–	–	–	–	–	–
VR-12	VR-12	–	–	–	–	–	–	–	–	–
NRS	–	–	–	–	NRS rest NRS activity	–	–	–	–	–
OMERACT-OARSI	–	–	–	–	–	–	–	–	OMERACT-OARSI	–
VAS	–	–	–	–	–	–	–	–	VAS	EQ VAS
Time points being collected										
Time point	Pre-op 1 yr post-op	–	–	–	Pre-op 6 mos post-op 1 yr post-op	–	6 mos post-op 5 yrs post-op 10 yrs post-op 15 yrs post-op 20 yrs post-op	–	Pre-op 1 yr post-op	Pre-op post-op

KOOS knee injury and osteoarthritis outcome score, *EQ-5D* EuroQol-5D, *PROMIS* patient-reported outcomes measurement information system, *VR-12* veterans RAND 12, *NRS* numeric rating scale, *OMERACT–OARSI* outcome measures in arthritis clinical trials – Osteoarthritis research society international, *VAS* visual analogue scale

Take-Home Messages

- The aggregation of data via registries is essential to allow for adequate statistical analysis, the ability to track long-term results, and recurring analysis to identify trends in care.
- The first institutional-based registry began at the Mayo Clinic, Rochester, Minnesota in 1965.
- Registries have now grown to the national scale, with the first national registry formed in Sweden in 1974.
- The American Joint Replacement Registry (AJRR) is a national registry in the United States, established and managed by the American Association of Orthopedic Surgeons (AAOS) in 2011.
- With all the success of national registries, there is a danger of using large observational data sets to make erroneous conclusions. Correlations can be identified but causation cannot be concluded.
- Pooled data from international registries demonstrates 82% TKA survivorship at 25-year follow-up.
- Traditional TJA registries were designed to collect data useful to monitoring implant survival and failure as defined by revision rates. While the implant revision rate remains an important outcome, registries are currently utilizing patient-reported outcome measures (PROMs) to contextualize patient function prior to a revision

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