Curr Rev Musculoskelet Med (2017) 10:240–252
DOI 10.1007/s12178-017-9408-5

Arthroplasty registries around the world: valuable sources of hip implant revision risk data

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Published online: 23 March 2017

Abstract
Purpose of Review National and regional arthroplasty registries have proliferated since the Swedish Knee Arthroplasty Register was started in 1975. Registry reports typically present implant-specific estimates of revision risk and patient- and technique-related factors that can inform clinical decision-making about implants and techniques. However, annual registry reports are long and it is difficult for clinicians to extract comparable revision risk data. Since implants may appear in multiple registry reports, it is even more difficult to gather relevant data for clinical decision-making about implant selection. The purpose of this paper is to briefly describe arthroplasty registry concepts, international registries around the world, US registries, and provide a parsimonious summary of total hip arthroplasty (THA) implant revision risk reports across registries.
Recent Findings Revision risk data for conventional stem/cup combinations reported by the Australian, R.I.P.O. (Italian), Finnish, and Danish registries are summarized here. These registries were selected because they presented 10-year data on revision risk by stem/cup combination. Four tables of revision risk are presented based on fixation: cemented, uncemented, hybrid, and reverse hybrid. Review of these tables show there is wide variation in revision risk across conventional THA implants. It also demonstrates that some cemented implants have better 10-year risk than the best uncemented implants.
Summary Many arthroplasty registries prepare annual reports that include revision risk data for implants and they are posted on the registry websites. Arthroplasty surgeons should stay current with these registry reports on implant performance and potential outliers and keep them in mind when making implant decisions.

Keywords Arthroplasty · Registry · Implants · Revision · Hip

Introduction

Patient registries are powerful tools for quality improvement in arthroplasty. A patient registry is a systematic collection of data on patient demographics, procedures, devices used, and outcomes for a well-defined cohort of patients. They can be used for research and quality improvement. Arthroplasty registries may present data on patient demographics to describe the population getting the procedures, patterns of utilization over time, revision risks, and patient-reported outcomes (PROS). Most existing registries are focused on revision risk data, but they are increasingly incorporating PROS data.

Arthroplasty registries are an integral component of medical device post-market surveillance. The metal-on-metal ASR resurfacing and ASR XL acetabular system implants were identified as having excessively high-revision risks by the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), and this finding was confirmed by the National Joint Replacement Registry of England, Wales, and Northern Ireland (NJR) and the New Zealand Registry. This resulted in the voluntary recall of the ASR devise worldwide. Because revision risks are typically a few percent or less within the first 5 or 10 years, very large

This article is part of the Topical Collection on *Orthopaedic Health Policy*

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numbers of patients are required to identify poorly performing implants quickly. Single-institution clinical studies and registries are therefore poorly suited for this purpose; large regional and national registries are necessary.

Registry data are also very important sources of data for evidence-based medical decision-making. National arthroplasty registries have also been shown to provide different estimates of revision risk than publications written by financially conflicted investigators [1]. This is particularly important in orthopedics because of the extensive relationships between surgeon innovators and implant manufacturers. Labek et al. [1] showed that the revision risk reported by financially conflicted authors was lower than what was found in national registries for the same devices. Surgeons depend on reports by clinical investigators to make evidence-based decisions on implant selection. They need unbiased information, and registries are better suited to provide data on a more generalizable, real-world experience.

Most national registries publish a periodic report, usually annually. They are extensive sources of data. However, the very fact that they provide extensive data makes it difficult to extract revision risk data on implants. Surgeons must comb through hundreds of pages of tables and figures for each national registry to identify useful data and then collate and cross-reference this across reports. To make registry data more useful to the practicing orthopedic surgeon we have compiled a summary of revision risk data for total hip arthroplasty (THA) implants. The purpose of this paper is to explain the current state of regional and national arthroplasty registries around the world and present our summary of THA implant revision risk to 10 years.

Registry concepts

There are a number of important concepts necessary to interpret reports on registry data: data coverage, data completeness, data accuracy, definition of a revision, device library, and signal detection. Coverage is the percent of the target population captured by the registry. For example, if the target is all elective primary and revision total hip and knee arthroplasty cases performed in a country, then the coverage would be the percent of these cases that get entered into the registry. Each case has a number of data fields to be completed. Data completeness refers to the extent that all of these fields are complete for the cases entered. Data accuracy refers to the correctness of the data entered.

Types of registry data are classified into four levels: level I is basic data about the patient and procedure (name, medical record number/national medical ID, type of procedure, primary/revision, device data, etc.); level II is demographic and comorbidity data about the patient; level III is patient-reported outcome data; and level IV is radiographic data. Most registries focus on level I data, and many only collect level I data because data collection is expensive. Level II data is necessary for risk-adjustment of adverse event outcome risks. Level III is currently a hot topic around the world and it is of particular interest in the USA because of new payment models that require collection and reporting PROS data. Very few national registries routinely collect level IV data, but many single-institution registries include imaging data.

Arthroplasty registries commonly use revision as an endpoint, although many are working to add PROS to measure functional improvement. While the definition of a revision procedure may seem obvious at first, it is more subtle when implementing a registry and understanding registry data. A registry may define it as the replacement of any implanted device or just a bone-fixed device. This affects, for example, whether a liner exchange is coded as a revision procedure. It is important to carefully read registry reports for the definition.

Arthroplasty registries typically capture information about implanted devices in order to compute revision risk statistics for implants. Data capture methods range from paper forms to Web-based entry and administrative file upload of the hospital's supply chain data. They usually include bar code information. To get from bar code data to meaningful fields to analyze, the data need to be transformed to manufacturer, product name, and feature information. Feature fields may include material, bearing surface, surface coating, head diameter, etc. This is done using a device library, which is a database of catalog numbers, manufacturer names, product names, and feature fields. It serves as a "look up table" in the data processing scheme of registries. Registries have developed their own libraries over time, and they are not all the same. However, there is an effort being led by the International Consortium of Orthopaedic Registries (ICOR) to harmonize the libraries. Much progress has been made and the resulting library will be made available to all registries through the International Society of Arthroplasty Registries (ISAR). It is important to note that the developer of a library has to decide on an implant taxonomy to use [2]. For example, suppose a company chooses to make a new version of a cobalt chromium alloy implant using titanium instead, but with the exact same dimensions and surface coating. Are the two stems the same or different? The materials are different; the geometry is the same. The library developer has to make such a decision when creating a label (or product name) to use when reporting the implant. Inconsistencies in library taxonomy can complicate the interpretation of registry data.

Global overview of arthroplasty registries

The first nationwide arthroplasty registries were developed in the 1970s in Sweden. The Swedish Knee Arthroplasty Register [3] was started in 1975 and the Swedish Hip

Arthroplasty Register [4] was initiated in 1979. Many more countries have developed arthroplasty registries since then: Australia, Belgium, Canada, Croatia, Denmark, Netherlands, Egypt, Finland, France, Germany, Hungary, New Zealand, Norway, Pakistan, Portugal, Romania, Slovenia, Slovakia, Switzerland, and the USA. The National Joint Registry of England, Wales, Northern Ireland, and the Isle of Man (NJR) covers most of the UK but does not include Scotland (it has its own registry [5]). Regional registries have also been developed in Europe. In Italy, there is the Registro dell'implantologia Protesica Ortopedica (R.I.P.O) and in Spain, there is the Catalan Arthroplasty Register. Almost all of these registries publish annual reports in PDF format on their websites. These registry reports provide extensive information on demographics, surgical techniques, and quality measures. Many, but not all, also provide implant-specific revision risk data over time. The Finnish registry has moved from a PDF report to an online report-generating system.

The USA has national, regional, and institutional arthroplasty registries. The most established institutional arthroplasty registries are at the Mayo Clinic [6] and Massachusetts General Hospital [7]. The USA has other distinctly regional registries separate from the American Joint Replacement Registry: HealthEast [8], Kaiser Permanente [9], and Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI) [10]. The HealthEast is the oldest regional registry in the USA. It was started in 1991. It is based in a small health system in the twin cities (Minneapolis/St. Paul). It was created to manage implant costs and assess cost-efficiency of implants. The Kaiser Permanente (KP) registry started in 2001. Kaiser Permanente is an integrated health system and is primarily located in California, but has hospitals across the country. KP has analyzed implants based on revision risk [11] and developed risk calculators [12]. KP does not publish an annual report; information about its results are available in the peer-reviewed literature [13, 14]. MARCQI is a state-wide registry in Michigan that started in 2012 [10] and collects data on 95% of the elective total hip and knee arthroplasty cases performed in Michigan; it is based on the quality improvement collaborative model pioneered by the Northern New England Cardiovascular Study Group [15]. MARCQI has over 160,000 cases in the registry from 59 hospitals representing cases from over 400 surgeons; it holds three to four meetings a year for participating hospitals and physicians to see risk-adjusted outcome data and share best practices for quality improvement. MARCQI has demonstrated its ability to publish observational research and reduce the risk of blood transfusion. [16–18].

The USA is a difficult environment for the development of multi-institutional arthroplasty registries due to financial, legal, and regulatory challenges. Starting in 1997, the Musculoskeletal Outcomes Data Evaluation and Management System (MODEMS) was an American Academy of Orthopaedic Surgeons (AAOS) initiative that attempted to develop a national registry [19]. The project was terminated by AAOS in 2000 due to low participation rates and incomplete data. Its failure has been largely attributed to reliance on voluntary surgeon reporting and data entry.

Since then, several organizations have attempted to develop arthroplasty registries with a nationwide footprint. The Functional Outcomes Research for Comparative Effectiveness in Total Joint Replacement and Quality Improvement (FORCE-TJR) registry was developed with support from the Agency for Healthcare Quality and Research [20] that was started in 2010 and was funded for 5 years. During that time, 30,000 cases were collected from a sample of physician practices across the country. FORCE-TJR did not achieve comprehensive coverage across the country but it has made substantial contributions to the literature, especially in the areas of risk-adjustment [21] and patient-reported outcomes [22]. FORCE-TJR continues to follow these patients and has collected additional patients through other mechanisms. Like FORCE-TJR, the KP registry does not provide comprehensive coverage across the USA, but does have participating hospitals in many states. The American Joint Replacement Registry (AJRR) aims to be a comprehensive joint replacement registry for the USA; it started in 2010 and has 417 participating hospitals [23]. In 2016, it absorbed the California Joint Replacement Registry (CJRR). The CJRR is operated by AJRR but maintains a separate brand identity.

Summary of implant revision risk data

Many registry reports include data on revision risk by implant. There are two basic ways they report risk: (1) the Kaplan-Meier method for analyzing time-to-revision data, and (2) the rate of revisions per 100 component years. The Kaplan-Meier method computes the fraction of cases not having a revision t years after the primary procedure, $S(t)$. Some registries report this as a percentage, i.e., $100S(t)$; others, such as the Australian registry, report the "cumulative percent revision" (CPR), which is $100(1\text{-}S(t))$. The Kaplan-Meier estimate may be problematic because it does not revise the population at risk as patients die. However, studies of NJR data show that this effect is minimal up to 10 years [24•].

Registry reports are extensive and can be hundreds of pages long. Thus, it can be difficult and time-consuming for clinicians, who often have little statistical training, to extract and interpret relevant data. In order to provide registry data in a more user-friendly way, we have created tables that summarize conventional implant-specific revision risks by stem/cup combination. We reviewed the annual reports from the registries listed above based on three criteria: (1) revision risk in Kaplan-Meier or CPR form, (2) 10-year or longer data, and (3)

Table 1 Revision risk (%) for cemented implants with at least one registry reporting 10-year data

Stem	Cup	Registry[+]	Number (*N*)	1 year	5 years	10 years
MS-30	Low Profile Muller	NJR (UK)	2,669	0.23 (0.1, 0.52)	0.72 (0.42, 1.25)	1.03 (0.51, 2.07)
Exeter V40	Elite Plus Cemented	NJR (UK)	7,513	0.44 (0.31, 0.63)	1.09 (0.85, 1.4)	1.66 (1.19, 2.3)
Exeter V40	Opera	NJR (UK)	2,801	0.36 (0.2, 0.67)	1.15 (0.78, 1.69)	1.78 (1.2, 2.64)
Stanmore Modular	Stanmore-Arcom	NJR (UK)	4,769	0.37 (0.23, 0.59)	1.36 (1.03, 1.79)	1.93 (1.43, 2.59)
C-Stem Cemented	Elite Plus Ogee	NJR (UK)	4,404	0.4 (0.25, 0.64)	1.18 (0.87, 1.59)	2.02 (1.51, 2.69)
Charnley Flanged	Charnley Standard	Danish	134		0.8 (0.0, 2.4)	2.4 (0.0, 6.5)
Exeter V40	Elite Plus Ogee	NJR (UK)	21,010	0.35 (0.28, 0.44)	1.11 (0.96, 1.29)	2.42 (2.0, 2.89)
Exeter V40	Cenator Cemented	NJR (UK)	2,501	0.49 (0.28, 0.85)	2.07 (1.54, 2.77)	2.71 (2.01, 3.64)
Exeter V40	Contemporary	NJR (UK)	75,093	0.48 (0.43, 0.54)	1.46 (1.36, 1.57)	2.92 (2.61, 3.26)
Charnley Cemented	Charnley Cemented	NJR (UK)	10,746	0.34 (0.25, 0.47)	1.38 (1.16, 1.64)	2.99 (2.58, 3.26)
CPT	Elite Plus Ogee	NJR (UK)	2,805	0.62 (0.39, 1.0)	1.91 (1.41, 2.59)	3.04 (2.03, 4.56)
CPT	ZCA	NJR (UK)	10,259	0.72 (0.57, 0.91)	1.91 (1.62, 2.25)	3.6 (2.91, 4.46)
CPT*	ZCA*	Danish	3,061		2.0 (1.5, 2.6)	5.3 (2.2, 8.2)
Exeter	Exeter Duration	Danish	1,898		3.2 (2.2, 4.1)	3.7 (2.3, 5.0)
Exeter V40	Exeter Duration	NJR (UK)	15,613	0.58 (0.47, 0.71)	1.68 (1.47, 1.91)	3.73 (3.24, 4.29)
JVC	MULLER	RIPO	326		1.6 (0.2, 3.0)	3.9 (1.5, 6.4)
Charnley Cemented	Charnley Ogee	NJR (UK)	9,594	0.38 (0.28, 0.53)	1.88 (1.61, 2.19)	4.09 (3.55, 4.71)
Lubinus SP II	Lubinus	Danish	6,990		2.5 (2.1, 3.0)	5.1 (4.0, 6.2)
MRL	MULLER	RIPO	305		3.5 (1.4, 5.7)	5.2 (2.5, 7.9)
Elite Plus	Charnley Standard	Danish	346		3.0 (1.1, 4.8)	5.8 (2.6, 8.9)
Exeter	Mallory-Head	Danish	142		5.8 (0.6, 10.7)	5.8 (0.6, 10.7)
EXETER	CONTEMPORARY	RIPO	485		4.0 (2.1,5.9)	5.8 (3.2,8.4)
Taperloc	Muller Hi Wall	Danish	191		4.6 (1.3, 7.7)	6.1 (1.9, 10.0)
Charnley Round-back	Charnley Ogee	Danish	600		3.3 (1.7, 4.9)	6.2 (2.8, 9.5)
Charnley Round-back	Charnley Standard	Danish	109		2.9 (0.0, 6.0)	6.2 (0.0, 12.1)
ITH	Richards Modular	Danish	199		1.6 (0.0, 3.3)	6.2 (2.2, 10.0)
Exeter Universal	Exeter Contemporary	Finnish	11,928	1.6 (1.4, 1.8)	3.6 (3.2, 3.9)	6.7 (6.1, 7.3)

Table 1 (continued)

Stem	Cup	Registry[+]	Number (*N*)	1 year	5 years	10 years
Charnley Flanged	Charnley Ogee	Danish	1,059		2.6 (1.6, 3.6)	6.8 (4.5, 9.0)
Exeter Universal	Exeter All Poly	Finnish	6,263	1.4 (1.1, 1.6)	4.0 (3.5, 4.5)	7.4 (6.7, 8.1)
Elite Plus	Charnley Ogee	Danish	320		3.1 (1.2, 5.0)	7.5 (3.9, 10.9)
Bi-Metric (titanium)	Muller	Danish	2,487		4.6 (3.7, 5.5)	7.6 (6.1, 9.1)
Lubinus SP II	Link FC	Finnish	1,269	1.9 (1.1, 2.7)	4.0 (2.9, 5.1)	7.6 (0.0, 9.3)
Elite Plus Flanged	Elite Ogee	Finnish	506	0.6 (0.0, 1.3)	4.5 (2.6, 6.4)	7.8 (5.2, 10.2)
Spectron EF	Reflection All Poly	Finnish	5,704	1.1 (0.9, 1.4)	2.8 (2.4, 3.2)	7.8 (6.9, 8.8)
Muller Monoblock	Muller Std	Finnish	2,908	0.7 (0.4, 1.0)	3.6 (2.9, 4.3)	7.9 (6.8, 9.0)
Lubinus SP II	Lubinus Eccentric	Finnish	3,680	1.1 (0.8, 1.5)	4.3 (3.6, 4.9)	8.0 (7.0, 9.0)
Lubinus SP II	Link IP	Finnish	8,957	1.3 (1.1, 1.5)	4.3 (3.9, 4.7)	8.4 (7.8, 9.1)
Exeter	Exeter All Plast	Danish	4,542		3.6 (3.0, 4.1)	8.6 (7.2, 9.9)
McKee Arden	McKee Arden	Finnish	615		2.3 (1.0, 3.6)	9.9 (6.9, 12.8)
Taperloc	Muller	Danish	441		4.9 (2.7, 7.0)	10.3 (5.7, 14.7)
Biomet Interlock	Biomet All Poly	Finnish	315	1.0 (0.0, 2.1)	6.4 (3.6, 9.2)	11.0 (7.2, 14.7)
ABG (S)	ABG (S)	Finnish	491	1.9 (0.6, 3.1)	6.7 (4.3, 9.0)	12.0 (8.8, 15.2)
Lubinus IP	Link IP	Finnish	7,628	0.4 (0.2, 0.5)	3.8 (3.4, 4.3)	12.3 (11.5, 13.1)
Biomet Interlock	Biomet Muller-Type	Finnish	688	0.2 (0.0, 0.4)	6.1 (4.2, 8.0)	12.6 (9.7, 15.3)
Charnley	Charnley LPW	Finnish	2,158	0.6 (0.2, 0.9)	4.5 (3.6, 5.4)	13.1 (11.5, 14.7)
Exeter	Exeter Metal Backed	Finnish	1,234	0.3 (0.0, 0.7)	4.4 (3.2, 5.6)	14 (11.8, 16.2)
Muller SLS Titanium	Muller Std	Finnish	347	1.2 (0.0, 2.3)	7.9 (4.9, 10.8)	14.2 (10.1, 18.1)
Bi-Metric (titanium)	Charnley Ogee	Danish	267		3.1 (0.8,5.4)	14.3 (3.1,24.2)
Lubinus SP I	Link IP	Finnish	679	0.4 (0.0, 1.0)	2.5 (1.3, 3.7)	14.5 (11.5, 17.4)
Elite Plus Flanged	Elite Plus LPW	Finnish	1,101	1.4 (0.7, 2.1)	8.0 (6.4, 9.6)	14.9 (12.6, 17.2)
Brunswick	Brunswick	Finnish	373	0.5 (0.0, 1.3)	3.0 (1.3, 4.8)	16.6 (12.4, 20.6)
Christiansen	Christiansen	Finnish	572	0.2 (0.0, 0.5)	14.8 (11.6, 17.8)	36.2 (31.7, 40.5)

*Denotes the stem/cup combination has been moved in the table to be close to the data from another registry

AOANJRR Australian Orthopaedic Association National Joint Replacement Registry; *NJR* (UK) National Joint Registry of England, Wales, Northern Ireland, and the Isle of Man; *RIPO* Registro dell'implantologia Protesica Ortopedica (Italy)

Table 2 Revision risk (%) for uncemented implants with at least one registry reporting 10-year data

Stem	Cup	Registry	Number (*N*)	1 year	5 years	10 years
Summit	Pinnacle	AOANJRR	3,695	1.0 (0.7, 1.4)	1.8 (1.3, 2.3)	2.6 (1.9, 3.4)
Summit*	Pinnacle*	Finnish	5,767	2.1 (1.7, 2.5)	4.2 (3.5, 4.9)	13.0 (10.9, 15.0)
Protasul Spotorno	Trilogy	Danish	140		3.1 (0.0, 6.2)	3.1 (0.0, 6.2)
CLS	Standard cup	RIPO	322		1.3 (0.0, 2.5)	3.1 (1.1, 5.1)
Modulus hip system	Delta PF	RIPO	352		2.5 (0.8, 4.2)	3.1 (1.0, 5.3)
Corail	Trilogy	NJR (UK)	2,721	0.64 (0.4, 1.02)	1.7 (1.25, 2.33)	3.27 (2.23, 4.78)
Secur-Fit Plus	Trident (Shell)	AOANJRR	5,447	1.2 (0.9, 1.5)	2.3 (1.9, 2.8)	3.5 (3.0, 4.1)
Furlong HAC Stem	CSF	NJR (UK)	16,226	1.0 (0.85, 1.16)	2.1 (1.88, 2.34)	3.68 (3.28, 4.12)
ABG II	ABG II	RIPO	1,759		2.0 (1.3, 2.7)	3.9 (2.9, 5.0)
ABG II*	ABG II*	Finnish	2,400	3.1 (2.4, 3.8)	5.6 (4.6, 6.5)	8.0 (6.9, 9.2)
ABG II*	ABG II*	AOANJRR	2,944	1.8 (1.4, 2.4)	4.1 (3.5, 4.9)	6.7 (5.8, 7.8)
ABG II*	ABG II (Shell/Insert)*	AOANJRR	870	1.5 (0.9, 2.6)	3.0 (2.0, 4.4)	7.7 (5.8, 10.1)
VERSYS FIBER	TRILOGY	RIPO	496		3.3 (1.7, 4.9)	4.0 (2.2, 5.8)
Secur-Fit	Trident (Shell)	AOANJRR	8,237	1.6 (1.3, 1.9)	3.1 (2.7, 3.5)	4.1 (3.6, 4.7)
Citation	Trident (Shell)	AOANJRR	1,147	1.7 (1.1, 2.7)	3.2 (2.3, 4.4)	4.2 (3.1, 5.7)
Synergy	Reflection (Shell)	AOANJRR	7,731	1.6 (1.3, 1.9)	2.7 (2.4, 3.1)	4.2 (3.7, 4.7)
Synergy*	Reflection*	RIPO	418		2.6 (0.8, 4.4)	6.3 (2.8, 9.8)
CFP	CFP	RIPO	406		2.3 (0.8, 3.8)	4.3 (2.0, 6.5)
CLS	Fitmore	RIPO	766		2.8 (1.6, 4.0)	4.3 (2.8, 5.9)
CLS*	Fitmore*	AOANJRR	674	1.8 (1.0, 3.1)	4.4 (3.0, 6.3)	5.6 (4.0, 7.9)
Accolade	Trident	NJR (UK)	21,637	0.94 (0.81, 1.07)	2.84 (2.58, 3.13)	4.35 (3.42, 5.53)
Accolade I*	Trident (Shell)*	AOANJRR	9,017	1.6 (1.4, 1.9)	3.8 (3.4, 4.2)	5.5 (4.8, 6.2)
Epoch	Trilogy	AOANJRR	1,020	2.5 (1.7, 3.6)	3.6 (2.6, 4.9)	4.4 (3.2, 5.9)
Natural Hip	Fitmore	AOANJRR	889	1.0 (0.5, 1.9)	2.4 (1.6, 3.7)	4.4 (3.1, 6.2)
Bi-Metric (titanium)	Universal	Danish	640		3.6 (1.9, 5.4)	4.6 (2.3, 6.9)
S-Rom	Duraloc Option	AOANJRR	666	1.5 (0.8, 2.8)	3.4 (2.2, 5.0)	4.7 (3.3, 6.6)
Taperloc	Mallory-Head	AOANJRR	1,415	1.7 (1.2, 2.6)	2.9 (2.1, 4.1)	4.8 (3.5, 6.4)

Table 2 (continued)

Stem	Cup	Registry	Number (*N*)	1 year	5 years	10 years
VerSys	Trilogy	AOANJRR	4,303	2.4 (2.0, 2.9)	3.7 (3.2, 4.3)	4.8 (4.1, 5.6)
S-Rom	Pinnacle	AOANJRR	2,777	2.3 (1.8, 2.9)	3.9 (3.2, 4.7)	5.0 (4.0, 6.4)
PCA Meridian	PCA Vitalock	Finnish	458	1.1 (0.1, 2.0)	3.8 (2.0, 5.6)	5.0 (3.0, 7.1)
CONUS	FITMORE	RIPO	1,111		2.9 (1.8, 3.9)	5.1 (3.4, 6.8)
SL-Plus	EP-Fit Plus	RIPO	1,911		3.3 (2.4, 4.2)	5.1 (3.2, 7.0)
SL-Plus*	EP-Fit Plus*	AOANJRR	2,257	1.7 (1.2, 2.3)	3.5 (2.8, 4.4)	5.8 (4.6, 7.4)
SL-Plus*	EP-Fit Plus*	NJR (UK)	4,750	1.25 (0.97, 1.61)	3.97 (3.42, 4.62)	6.56 (5.25, 8.18)
Alloclassic	Allofit	AOANJRR	5,457	1.4 (1.1, 1.8)	3.0 (2.5, 3.5)	5.2 (4.4, 6.0)
SL-PLUS	CLS	RIPO	311		3.0 (1.1, 5.0)	5.2 (1.7, 8.7)
Mallory-Head	Mallory-Head	AOANJRR	2,856	1.8 (1.4, 2.4)	3.1 (2.5, 3.8)	5.3 (4.4, 6.4)
Omnifit	Trident (Shell)	AOANJRR	1,271	1.9 (1.3, 2.8)	4.1 (3.1, 5.4)	5.4 (4.2, 6.9)
Corail	Pinnacle	AOANJRR	26,938	1.7 (1.5, 1.8)	3.1 (2.9, 3.4)	5.4 (4.5, 6.5)
Corail*	Pinnacle*	NJR (UK)	95,702	0.81 (0.76, 0.87)	2.89 (2.75, 3.03)	7.94 (7.1, 8.88)
Bi-Metric (titanium)	Harris-Galante II	Danish	188		2.8 (0.3, 5.1)	5.4 (1.7, 9.0)
Bi-Metric Collarless*	HGPII*	Finnish	364	1.1 (0.0, 2.2)	4.0 (1.9, 6.0)	11.7 (8.2, 15.1)
Corail	Duraloc	NJR (UK)	4,036	0.75 (0.52, 1.07)	2.49 (2.04, 3.03)	5.57 (4.65, 6.68)
Corail*	Duraloc*	AOANJRR	1,433	1.4 (0.9, 2.2)	2.8 (2.1, 3.9)	5.7 (4.4, 7.6)
CLS	CLS	RIPO	1,517		2.4 (2.4, 3.2)	5.6 (4.3, 6.9)
RECTA	FIXA	RIPO	2,725		3.8 (3.0, 4.5)	5.8 (4.7, 6.9)
APTA	FIXA	RIPO	1,704		3.3 (2.4, 4.2)	6.0 (4.3, 7.7)
CONUS	CLS	RIPO	592		3.0 (1.6, 4.4)	6.1 (4.0, 8.2)
ABG I	ABG II	Finnish	2,361	1.8 (1.3, 2.4)	3.2 (2.5, 3.9)	6.1 (5.1, 7.1)
CLS	Allofit	AOANJRR	818	1.5 (0.9, 2.6)	3.7 (2.6, 5.4)	6.3 (4.6, 8.6)
Citation	Vitalock	AOANJRR	555	0.5 (0.2, 1.7)	2.8 (1.7, 4.5)	6.6 (4.7, 9.2)
AnCA Fit	AnCA Fit	RIPO	2,873		4.1 (3.3, 4.8)	6.6 (5.7, 7.6)
CBC	EXPANSION	RIPO	1,171		5.5 (4.1, 7.0)	6.8 (5.0, 8.5)
Alloclassic	Fitmore	AOANJRR	1,765	2.8 (2.1, 3.7)	5.1 (4.2, 6.3)	6.9 (5.7, 8.4)

Table 2 (continued)

Stem	Cup	Registry	Number (*N*)	1 year	5 years	10 years
Bi-Metric Collared	Vision	Finnish	365	1.1 (0.0, 2.2)	3.1 (1.3, 4.9)	6.9 (4.1, 9.5)
SL-PLUS	BICON PLUS	RIPO	915		4.2 (2.9, 5.5)	7.2 (5.1, 9.4)
Bi-Metric (titanium)	Ranawat-Burstein	Danish	840		3.1 (1.7, 4.5)	7.3 (3.5, 11.0)
Summit	Pinnacle (MoM)	AOANJRR	784	1.5 (0.9, 2.7)	3.3 (2.2, 4.8)	7.4 (5.5, 10.0)
CORAIL	PINNACLE SECTOR II	RIPO	604		4.2 (2.4, 5.9)	7.4 (3.8, 11.0)
F2L	SPH-Blind	AOANJRR	614	3.1 (2.0, 4.8)	6.1 (4.5, 8.4)	7.6 (5.7, 10.0)
PROFEMUR Z	AnCA Fit	RIPO	420		5.8 (3.5, 8.0)	8.2 (5.5, 10.8)
Bi-Metric Collared	Trilogy	Finnish	267	2.3 (0.5, 4.1)	4.3 (1.8, 6.8)	8.3 (4.7, 11.7)
Bi-Metric (titanium)*	Trilogy (high)*	Danish	4,891		4.1 (3.4, 4.8)	8.6 (4.6, 12.4)
ABG II	Trident (Shell)	AOANJRR	2,409	2.6 (2.1, 3.4)	5.2 (4.3, 6.2)	8.4 (7.0, 10.0)
ABG II*	TRIDENT*	RIPO	389		5.4 (3.1, 7.7)	8.5 (5.4, 11.6)
ABG II*	Trident PSL*	Finnish	500	4.0 (2.3, 5.7)	7.1 (4.8, 9.4)	10.1 (7.3, 12.9)
AML	Duraloc 300	Danish	274		3.2 (1.1, 5.3)	8.4 (2.2, 14.1)
Bi-Metric Collarless	Vision	Finnish	4,446	2.7 (2.2, 3.2)	5.4 (4.7, 6.0)	8.9 (8.0, 9.9)
Bi-Metric Collarless	Exceed Hap	Finnish	1,460	2.7 (1.9, 3.6)	4.9 (3.7, 6.1)	10.3 (7.4, 13.1)
Omnifit	Secur-Fit	AOANJRR	508	3.2 (1.9, 5.1)	6.6 (4.7, 9.2)	10.9 (8.4, 14.1)
Bi-Metric Collarless	Biomex	Finnish	333	2.1 (0.6, 3.6)	3.6 (1.6, 5.6)	11.2 (7.6, 14.6)
Bi-Metric Collarless	M2a 38 One-Piece	Finnish	631	1.4 (0.5, 2.3)	3.8 (2.3, 5.3)	11.8 (7.5, 14.3)
Anatomic Mesh	HGPII	Finnish	984	0.9 (0.3, 1.5)	4.6 (3.3, 5.9)	12.5 (10.3, 14.6)
Taperloc	M2a (MoM)	AOANJRR	512	1.8 (0.9, 3.4)	7.4 (5.4, 10.1)	12.6 (9.6, 16.3)
PCA E-Series	PCA Cluster	Finnish	607	1.0 (0.2, 1.8)	3.9 (2.3, 5.4)	12.6 (9.7, 15.3)
Bi-Metric Collarless	PFU	Finnish	4,447	1.4 (1.0, 1.7)	4.7 (4.1, 5.3)	12.8 (11.7, 13.8)
Bi-Metric Collarless	Mallory	Finnish	838	2.2 (1.2, 3.1)	4.4 (3.0, 5.8)	13.2 (10.7, 15.6)
Corail	Pinnacle (MoM)	AOANJRR	966	2.2 (1.4, 3.3)	5.9 (4.6, 7.7)	13.4 (10.2, 17.6)
Bi-Metric Collared	PFU	Finnish	653	1.2 (0.4, 2.1)	5.5 (3.7, 7.2)	13.9 (11.2, 16.6)
Bi-Metric (titanium)	Mallory-Head	Danish	1,856		3.5 (2.3, 4.8)	14.7 (2.7, 25.2)
Mathys Isoelastic	RM	Finnish	1,355	1.6 (0.9, 2.2)	5.5 (4.3, 6.8)	14.8 (12.8, 16.9)

Table 2 (continued)

Stem	Cup	Registry	Number (*N*)	1 year	5 years	10 years
Bi-Metric Collarless	M2a 38 Flared	Finnish	1,944	1.9 (1.3, 2.5)	5.2 (4.2, 6.2)	15.1 (13.1, 17.0)
Biomet Head-Neck	PFU	Finnish	195	2.1 (0.0, 4.0)	5.3 (2.0, 8.5)	15.4 (10.0, 20.5)
Bi-Metric Collarless	M2a 38 Hemispherical	Finnish	510	1.4 (0.4, 2.4)	4.7 (2.8, 6.6)	16.2 (10.8, 21.2)
Synergy	BHR	Finnish	551	2.0 (0.8, 3.2)	5.6 (3.6, 7.5)	18.2 (13.3, 23.0)
PCA Standard	PCA Pegged	Finnish	762	0.7 (0.1, 1.2)	5.0 (3.4, 6.5)	18.9 (15.9, 21.8)
Biomet Dysplastic Stem	PFU	Finnish	275	3.6 (1.4, 5.8)	11.8 (7.9, 15.6)	19.5 (14.6, 24.2)
ABG I	ABG I	Finnish	794	1.0 (0.3, 1.7)	3.5 (2.1, 4.7)	20 (17.0, 22.9)
Lord Madreporique	Lord	Finnish	1,881	0.7 (0.4, 1.1)	5.6 (4.5, 6.7)	24.0 (21.9, 26.0)
Link RS	Link Lubinus K-Cup	Finnish	653	1.2 (0.4, 2.1)	9.2 (6.9, 11.4)	24.9 (21.3, 28.4)
Bi-Metric Collarless	Romanus	Finnish	483	1.7 (0.5, 2.8)	7.4 (5.0, 9.7)	26.2 (22.0, 30.1)
Summit	ASR	Finnish	620	3.1 (1.7, 4.4)	24.2 (20.6, 27.5)	49.6 (42.4, 55.9)
Bi-Metric Collarless	TTAP	Finnish	696	0.4 (0.0, 0.9)	23.5 (20.3, 26.7)	66.5 (62.6, 70.0)

*Denotes the stem/cup combination has been moved in the table to be close to the data from another registry

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an English-language version of the report. The rationale for 10-year data was its use by the UK's National Institute for Health and Care Excellence (NICE) in its guidance on THA implants [25••]. Five registries met these criteria: AOANJRR [26], NJR [27], R.I.P.O. (Italy) [28], Finland [29], and Denmark [30]. For those reports (R.I.P.O. and Denmark) reporting $100S(t)$, we converted data to CPR. All these reports categorize the stem/cup implant revision risks by fixation.

The results of this comprehensive review of conventional implant-specific revision risk data are presented in four tables organized by fixation: cemented (Table 1), uncemented (Table 2), hybrid (Table 3), and reverse hybrid (Table 4). Note we chose not to include resurfacing implants in the review. We included 1-, 5-, and 10-year data as well as the number of cases (*N*). Ninety-five percent confidence intervals are also provided below the point estimate in each table cell. Each table was constructed by first sorting based on 10-year revision risk and then similar implants were grouped together. Sorting was done from lowest to highest revision risk within each table. To make it easier for the reader to find multiple reports on the same devices, we collected the reports for similar implants from multiple registries into one location in each table. Implants that were moved are indicated by making the cup and stem names appear with the asterisk (*) notation. For example, in Table 2, the Summit/Pinnacle is listed in the first two rows. The first row is from the Australia registry report, and the 10-year revision risk point estimate is 2.6%. The next entry from Finland has a 10-year revision risk of 13.0%. We moved that entry from lower in the table to the second entry so the reader can easily see these two estimates of risk right next to each other. This procedure was followed for grouping ABG II/ABG II, Synergy/Reflection, Accolade I/Trident, SL-Plus/EP-Fit Plus, Corail/Pinnacle, Bi-Metric Collarless/HGPII, ABG II/Trident and rows in Table 2 and Exeter V40/Trilogy and CPT/Trilogy rows in Table 3.

Discussion

Because these data are provided to inform clinical decision-making, it is imperative to understand the limitations of implant revision risk data obtained from registry reports. Most importantly, registry data are observational data. As such, there are numerous potential sources of bias. For example, an implant that appears to perform poorly may be one that is used by a low number of

Table 3 Revision risk (%) for hybrid implants with at least one registry reporting 10-year data

Stem	Cup	Registry	N	1 year	5 years	10 years
EXETER	TRIDENT	RIPO	342		0.6 (0.0, 1.5)	0.6 (0.0, 1.5)
Exeter V40	Trident	NJR (UK)	42,263	0.57 (0.5, 0.65)	1.46 (1.32, 1.61)	2.3 (2.04, 2.6)
Exeter V40*	Trident (Shell)*	AOANJRR	41,949	1.2 (1.1, 1.3)	2.4 (2.2, 2.6)	4.2 (3.9, 4.6)
Exeter V40	Trilogy	NJR (UK)	11,740	0.57 (0.45, 0.72)	1.35 (1.14, 1.6)	2.38 (1.98, 2.87)
Exeter V40*	Trilogy*	AOANJRR	605	1.7 (0.9, 3.1)	2.6 (1.6, 4.3)	4.8 (2.8, 8.2)
MS 30	Fitmore	AOANJRR	531	0.2 (0.0, 1.3)	1.4 (0.6, 3.0)	2.4 (1.2, 4.5)
Exeter V40	Mallory-Head	AOANJRR	1,296	0.5 (0.2, 1.1)	0.9 (0.5, 1.7)	3.0 (2.0, 4.6)
CPT	Harris-Galante II	Danish	125		0.6 (0.0, 1.9)	3.1 (0.0, 6.8)
Exeter V40	Vitalock	AOANJRR	1,959	0.9 (0.9, 1.5)	2.3 (1.7, 3.1)	3.3 (2.6, 4.3)
APTA	FIXA	RIPO	572		2.9 (1.5, 4.3)	3.4 (1.8, 4.9)
P507	DUOFIT PSF	RIPO	492		1.9 (0.7, 3.2)	3.5 (1.7, 5.3)
Exeter V40	ABG II	AOANJRR	1,071	1.1 (0.6, 2.0)	2.1 (1.3, 3.1)	3.6 (2.5, 5.0)
Omnifit	Trident (Shell)	AOANJRR	2,503	1.7 (1.3, 2.3)	3.0 (2.4, 3.8)	3.6 (2.8, 4.6)
CPT	Trilogy	NJR (UK)	13,344	0.84 (0.69, 1.01)	2.24 (1.93, 2.6)	3.61 (2.92, 4.46)
CPT*	Trilogy*	AOANJRR	6,818	1.6 (1.3, 1.9)	3.2 (2.8, 3.7)	5.0 (4.3, 5.8)
CPT*	Trilogy*	Finnish	342	2.1 (0.5, 3.5)	3.0 (1.1, 4.8)	5.4 (2.7, 7.9)
Exeter	Duraloc 300	Danish	955		3.5 (2.1, 4.8)	3.7 (2.3, 5.1)
MS 30	Allofit	AOANJRR	1,454	1.3 (0.8, 2.0)	2.3 (1.6, 3.3)	3.9 (2.9, 5.4)
Spectron EF	Reflection Interfit	Finnish	335	2.4 (0.7, 4.1)	3.7 (1.6, 5.7)	4.1 (0.0, 6.2)
CPCS	Reflection (Shell)	AOANJRR	2,813	0.9 (0.6, 1.4)	1.7 (1.3, 2.3)	4.6 (3.4, 6.2)
Exeter	Vitalock	AOANJRR	1,218	1.6 (1.0, 2.5)	2.5 (1.8, 3.6)	4.8 (3.6, 6.2)
Bi-Metric (titanium)	Harris-Galante II	Danish	206		4.8 (1.6, 7.8)	4.8 (1.6, 7.8)
C-Stem	Pinnacle	AOANJRR	754	1.9 (1.1, 3.2)	2.8 (1.8, 4.4)	4.9 (3.1, 7.6)
Exeter	Mallory-Head	Danish	1,477		2.3 (1.5, 3.2)	5.3 (2.2, 8.3)
Exeter Universal	Trident PSL	Finnish	1,299	1.6 (0.9, 2.2)	3.3 (2.3, 4.3)	5.3 (3.5, 7.1)
Spectron EF	Reflection (Shell)	AOANJRR	5,075	1.1 (0.8, 1.4)	2.7 (2.3, 3.2)	5.7 (4.9, 6.6)
Bi-Metric (titanium)	Harris-Galante	Danish	205		2.4 (0.3, 4.4)	5.9 (1.5, 10.2)

Table 3 (continued)

Stem	Cup	Registry	N	1 year	5 years	10 years
Exeter Universal	Biomex	Finnish	374	0.8 (0.0, 1.7)	1.9 (0.5, 3.4)	6.4 (3.6, 9.0)
Exeter Universal	ABG II	Finnish	919	1.2 (0.5, 1.9)	3.6 (2.3, 4.8)	6.4 (4.8, 8.1)
Exeter Universal	Trilogy	Finnish	403	1.8 (0.5, 3.0)	5.1 (2.9, 7.3)	6.9 (4.3, 9.5)
Muller Monoblock	RM with HA	Finnish	636	0.2 (0.0, 0.5)	2.1 (0.9, 3.2)	7.2 (4.9, 9.4)
C-Stem	Duraloc	AOANJRR	981	2.4 (1.6, 3.5)	4.0 (2.9, 5.5)	7.7 (6.0, 9.9)
BASIS	REFLECTION	RIPO	677		3.4 (1.9, 4.9)	8.1 (5.3, 10.9)
Exeter Universal	Vision	Finnish	261	3.5 (1.2, 5.7)	5.8 (2.8, 8.7)	9.2 (5.2, 13.1)
Exeter Universal	Profile Duraloc	Finnish	437	1.1 (0.1, 2.1)	5.2 (3.1, 7.3)	9.3 (6.4, 12.1)
Elite Plus	Duraloc	AOANJRR	1,078	2.0 (1.3, 3.0)	5.4 (4.2, 7.0)	9.7 (8.0, 11.9)
Bi-Metric (titanium)	Ranawat-Burstein	Danish	657		7.9 (5.4, 10.3)	11.8 (7.8, 15.6)
Bi-Metric (titanium)	Trilogy (high)	Danish	3,799		5.1 (4.2,6.0)	12.5 (5.3,19.2)
Exeter Universal	HGP II	Finnish	554	2.9 (1.5, 4.3)	6.3 (4.2, 8.4)	13.9 (10.7, 17.1)
Elite Plus Flanged	Profile Duraloc	Finnish	412	1.0 (0.0, 1.9)	6.1 (3.7, 8.5)	14.6 (10.8, 18.1)
Bi-Metric (titanium)	Universal	Danish	2,346		5.9 (4.8, 6.9)	15.1 (11.3, 18.7)
Taperloc	Trilogy (high)	Danish	926		8.1 (6.2, 10.0)	16.0 (11.7, 20.1)

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surgeons with worse outcomes but may perform differently in other hands. This is why we included the *N* column: a revision risk based on 30,000 cases is less likely to experience this kind of effect than one based on only 300 cases. Therefore, *N* should be considered in addition to the width of the confidence interval when interpreting a point estimate of CPR. Novel technologies are also often adopted at high volume centers first, which may produce early revision risk estimates that differ from what would occur in wide community practice. Learning curve effects [31•] are also not explicitly addressed in these tables. Finally, surgical technique and bearing surface technology evolve over time. Some data provided in these tables were collected earlier than others, so their revision risks may

Table 4 Revision risk (%) for reverse hybrid implants with at least one registry reporting 10-year data

Stem	Cup	Registry	Number (*N*)	1 year	5 years	10 years
Bi-Metric Collarless	Stanmore	Finnish	394	1 (0.0, 2.0)	3.9 (1.9, 5.8)	8.1 (5.4, 10.9)

*Denotes the stem/cup combination has been moved in the table to be close to the data from another registry

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have been affected by the use of different technology implanted using different techniques.

Interpretation of arthroplasty registry report revision risk data also requires recognizing the challenges of implant taxonomy [2]. Each implant comes in different sizes and often different versions. For example, many manufacturers offer an implant in a standard offset and high offset version. The operator of a registry has to decide whether these two versions should be lumped together or kept separate in the analysis. The same is true for implants that have the same shape but are made of two different materials. There is no worldwide consensus on grouping of implants in registry reporting. Moreover, registry reports are often not transparent about these decisions.

Of course, these limitations do not make registry data hopelessly flawed. The strengths and weaknesses should be considered together. Strengths of registry data include generalizability, statistical power, ability to capture revisions, and being less affected by financial conflict of interest. While randomized studies generally provide effect estimates that are less biased than observational ones, they are most often done by high-volume surgeons at high-volume centers. Consequently, their results may not accurately reflect how a stem/cup implant combination will perform in the wider community. The large size of registries provides better statistical power than single-center studies, which are often quite limited. This means that there is a better chance of detecting rare events in registry data, which is important when considering the low risk of revision in many modern implant designs. National registries are particularly noteworthy in their ability to capture revisions compared to single-institution studies because many patients go elsewhere for revision procedures. Without extensive and expensive data capture infrastructure, which single-institution studies often lack, it is hard to capture these revisions. Finally, revision risks reported in registries are often multiple times higher than those reported in peer-reviewed publications by implant developers or investigators, suggesting that registry data is less subject to conflict of interest. [1, 32].

Conclusions

The arthroplasty registry community has a culture of publishing annual reports of their results. The tables in this paper were constructed from those reports. It is important to know that these reports are available online and the interested reader can consult them in future years. Relying on peer-reviewed papers alone may lead the reader to selected results that may not be informative for their specific practices. An annual reading of the registry reports is encouraged to stay current on arthroplasty technology data.

Acknowledgments The authors would like to thank Blue Cross and Blue Shield of Michigan and Blue Care Network for its support of this project.

Compliance with ethics guidelines

Conflict of interest The authors report financial support for the Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI). The work done that is reported in this manuscript was done as part of MARCQI, so BCBSM/BCN funds were used.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Funding This work was done as part of the quality improvement work of MARCQI. Support for MARCQI is provided by Blue Cross and Blue Shield of Michigan and Blue Care Network as part of the BCBSM Value Partnerships program.

Disclaimer Although Blue Cross Blue Shield of Michigan and MARCQI work collaboratively, the opinions, beliefs and viewpoints expressed by the author do not necessarily reflect the opinions, beliefs and viewpoints of BCBSM or any of its employees.

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