The 2019 Annual Report is dedicated to Daniel J. Berry, MD, Immediate-past Chair of the American Joint Replacement Registry (AJRR), for his invaluable guidance and longtime support of the AJRR. As past President of AAOS, Dan has been a staunch advocate for the primacy of AAOS’ commitment to empowering its members with practical tools to improve patient outcomes, and has served as a mentor to many past and current members of the AJRR leadership. Dan’s leadership will continue to have a lasting impact on the field of total joint arthroplasty, and most importantly, the lives of the patients we are so fortunate to serve.

Kevin J. Bozic, MD, MBA
Chair, AJRR Steering Committee

Dedication

Contents

Foreword ......................................................... 1
Executive Summary ........................................... 2
About AJRR ..................................................... 4
Overall Results ................................................. 15
   Procedural Data Metrics ............................... 15
   Submitting Facilities .................................... 16
   Ambulatory Surgery Centers ......................... 17
   Submitting Surgeons .................................... 18
   Data Completeness ...................................... 19
Hip Arthroplasty ............................................... 21
   Hip Overview ............................................. 21
   Arthroplasty for Femoral Neck Fracture .......... 23
   Hip Resurfacing ......................................... 25
   Elective Primary Total Hip Arthroplasty .......... 26
   Revision Hip Arthroplasty ............................. 37
   Patient-Reported Outcome Measures (PROMs) .. 42
Knee Arthroplasty ............................................... 44
   Knee Overview ............................................ 44
   Primary Total Knee Arthroplasty ..................... 46
   Partial Knee Arthroplasty ............................. 56
   Revision Knee Arthroplasty ......................... 58
   Patient-Reported Outcome Measures (PROMs) .. 62
Appendices ...................................................... 64
   A. Data Element Review ............................... 64
   B. Audit of Registry Data .............................. 65
   C. AAOS Authorized Vendor Program ............... 66
   D. AJRR Committees .................................... 67
   E. Participating Institutions ......................... 68
   F. Clinical Survivorship Curve Methodology ....... 83
References ....................................................... 84
Foreword

This year marks an exciting year for the American Academy of Orthopaedic Surgeons (AAOS) and our cornerstone Registry for hip and knee arthroplasty, the American Joint Replacement Registry (AJRR). With over 1.2 million patients and over 1.7 million (and counting) hip and knee arthroplasty procedures currently captured in the Registry, the AJRR is the largest orthopaedic registry by annual procedure count.

We are proud to present this 2019 Annual Report, which reflects data related to hip and knee arthroplasty procedures performed in AJRR participating institutions between 2012 and 2018. Our primary goal is to provide data that is actionable to orthopaedic surgeons in their journey to improve the lives of millions of Americans who suffer from hip and knee arthritis. In addition to descriptive statistics related to the demographic, clinical, and implant characteristics associated with hip and knee arthroplasty procedures performed in the United States, this year’s report provides additional clinical insights and risk stratified outcome analyses related to Medicare patients who undergo hip and knee arthroplasty procedures. These analyses were made possible by the successful integration of Medicare claims data into the AJRR, which provides a more complete picture of our patient population and their associated comorbidities and outcomes, including longitudinal outcomes of patients who receive care at non-AJRR participating hospitals. The information in this year’s report gives the most comprehensive picture to date of patterns of hip and knee arthroplasty practice and outcomes in the United States.

The AAOS leadership and AJRR Steering Committee trust you will find the information in this report interesting, useful, and in some cases, actionable. With the rapid growth of AJRR capabilities, we look forward to being able to provide all of our stakeholders with valuable data that can be used to change practice and improve patient outcomes.

In closing, I would like to thank Kristina Rosinia, MPH, Director of AAOS Registries; David Lewallen, MD, Medical Director of the AJRR; Bryan Springer, MD, Chair of the AJRR Data Committee; James Browne, MD, Chair of the AJRR Publications Subcommittee and Editor, AJRR Publications; and Terence Gioe, MD, Editor of the AJRR Annual Report, for their tireless efforts to bring you this report.

As always, we appreciate your strong and consistent support of the AJRR and the patients we are so fortunate to serve.

With great humility and respect,

Kevin J. Bozic, MD, MBA
Chair, AJRR Steering Committee
Executive Summary

The American Joint Replacement Registry (AJRR) joined the AAOS Registry Program as the inaugural Registry in 2017. With oversight from the AAOS Registry Oversight Committee (ROC) and the AJRR Steering Committee, AJRR continues to work toward the AAOS Registry goal. Since then, the AAOS Registry Program has continued to grow adding registries from other anatomic sites and orthopaedic areas including the Shoulder & Elbow Registry (SER) and Musculoskeletal Tumor Registry (MsTR) while maintaining AJRR as the cornerstone.

The past year has been marked by a multitude of successes and growth for AJRR. This Annual Report represents over 1.5 million hip and knee procedures and over 1,200 enrolled sites with an overall cumulative procedural volume growth of 28.5% compared to the previous year. Much attention has been paid ensuring AJRR maintains as the national Registry for total joint arthroplasty. Additional highlights for the year include:

- **Ambulatory Surgery Centers (ASCs)** have historically not been strongly represented in AJRR as much of the procedural information in the Registry has come from hospitals. Wanting to provide ASCs and private practices access to data quality, analysis, and benchmarking, AAOS began implementing plans to better serve these sites. The first step was to focus on actively recruiting, educating and engaging ASCs. This strategic refocus has been successful, as the number of ASCs participating in the Registry grew by 38.7% between July 1, 2018 and August 1, 2019. To continue this trend, AAOS partnered with the Ambulatory Surgery Center Association (ASCA) and began a pilot program that provides the data submission framework necessary for ASCs with low-volume and/or limited technical capabilities. This partnership enables ASCs to demonstrate their value as viable sources of healthcare.

- **Patient-Reported Outcome Measures (PROMs)** are increasingly being utilized to evaluate success of a hip or knee arthroplasty procedure. Many orthopaedic stakeholders are finding benefit in capturing this patient perspective to best provide a full picture for surgical outcome evaluation. Recognizing this, AJRR has made a commitment to facilitating capture of this useful data. Specifically, AJRR continues to support the RegistryInsights® PROM platform for facilities to easily collect and upload PROM submissions to the Registry. Additionally, AJRR has formed multiple partnerships, expanding our Authorized Vendor Program, to include even more PROM technological vendors. These efforts have led to substantial growth in PROMs capture. By the end of 2018, 61 sites out of 821 (7.4%) submitted PROMs, compared to 6.3% the year prior. As of June 30, 2019, this number has more than doubled to 155.

- **Tracking and Monitoring Outcomes** with longitudinal patient information continues to be a focus of the AAOS Registry Program. To help sites best utilize Registry data for this purpose, RegistryInsights® has been expanded and enhanced over the past year. This allows individual participating institutions access to their own real-time dashboard comparing their metrics to the AJRR national benchmark. Separately, the sites’ surgeons have the ability to view their own dashboard based on data submitted on procedures they performed. Finally, for those needing more custom capabilities, AJRR offers either sites of service or surgeon-specific custom reports. This past year, AJRR has provided these reports allowing surgeons and participating institutions the ability to reuse their Registry data for internal performance measures or benchmarks.

- **Publications and Presentations Based Off AJRR Data** have been an important focus of AJRR over the past year. Through continuing education presentations at the 2019 National Association of Orthopaedic Nurses (NAON) Annual Meeting to podium presentations and posters at the 2018 American Association of Hip and Knee Surgeons (AAHKS), 2019 American Academy of Orthopaedic Surgeons (AAOS), 2019 International Society of Arthroplasty Registries (ISAR), 2019 The Knee Society, and 2019 The Hip Society Annual Meetings. Topics have included patient-reported outcome measures, infection, femoral neck fixation, migration, dual mobility, and more. This year, AJRR has been fortunate to publish in a number of peer-reviewed journals. Articles include “Perioperative periprosthetic femur fractures are strongly correlated with fixation method: An Analysis from the American Joint Replacement Registry (AJRR)” (Journal of Arthroplasty), “Early Results From the American Joint Replacement Registry: A Comparison With Other National Registries” (Journal of Arthroplasty), and “What Are the Migration Patterns for U.S. Primary Total Joint Arthroplasty Patients?” (Clinical Orthopaedics and Related Research).
• **The Ability to Reuse Registry Data** to enable performance measurement as well as facilitate national registry-driven quality improvement programs has been a concentration of the Registry over the past year. Now, AJRR data can be reused toward:

  - The Joint Commission (TJC) Advanced Certification for Total Hip and Total Knee Replacement
  - American Board of Orthopaedic Surgeons (ABOS) Maintenance of Certification (MOC) program for Part II Self-Assessment Examination (SAE) credit
  - Centers for Medicare & Medicaid Services (CMS) Bundled Payments for Care Improvement Advanced (BPCI-A) for the 2021 reporting year
  - CMS Comprehensive Care for Joint Replacement (CJR) Model
  - CMS Merit-based Incentive Payment System (MIPS) Promoting Interoperability (PI) and Quality Payment Program (QPP)
  - Accreditation Association for Ambulatory Health Care (AAAHC) Advanced Orthopaedic Certification
  - BlueCross BlueShield Blue Distinction Specialty Care
  - Blue Shield of California waiver of prior authorization for their patients’ hip or knee replacement procedures
  - Bree Collaborative
  - DNV GL Orthopaedic Center of Excellence
  - The Alliance QualityPath

To find out more about these and other ways to reuse Registry data please click [here](#).

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**2019 AJRR Annual Report Highlights**

The 2019 *American Joint Replacement Registry Annual Report* represents 1,525,435 primary and revision hip and knee arthroplasty procedures performed between 2012 and 2018. Primary knee (54.4%) and primary hip (32.7%) procedures made up the majority. Sex breakdown was 59.0% female and 41.0% male for all cases. The average age of a hip arthroplasty patient was 67.4 years and 66.7 years for all knee cases. Most of the patients in the data were white (72.1%) although race was unreported in 18.7% of cases. Among AJRR surgeons performing elective primary total hip arthroplasty and separately total knee procedures, the mean procedure count was 32.0 and 44.8 respectively.

Many trends identified in previous *AJRR Annual Reports* remain consistent. For hip arthroplasty procedures, there is still a trend towards increased ceramic heads and enhanced polyethylene liners. Usage of dual mobility constructs has continued to increase in both the primary and revision setting and for the treatment of femoral neck fractures while hemiarthroplasties still predominate, total hip arthroplasty usage has increased.

For total knee arthroplasties, the number of medial and lateral unicompartmental knee arthroplasty procedures still remain low at just 2.2% of all primary knee arthroplasties reported to AJRR for 2018. Although cemented fixation still predominates, the use of cementless fixation has seen an overall increase since 2012. Similar to past years, more than half of all primary total knee arthroplasty procedures in 2018 utilized posterior stabilized implants and there has been little change in the use of mobile-bearing designs in the revision setting which fluctuates from 17.0-19.1%.

Finally, enhanced analytics is always the goal of each *Annual Report*. With the continued growth of AJRR, analyses with Registry data will continue to mature. This year represents the second year completing survivorship curves and utilizing CMS data. Much time was spent establishing a consensus-driven methodology determined by multiple stakeholders. This framework provides a foundation ensuring strength in all analyses moving forward, progressing toward more sophisticated and detailed survivorship curves in the future.
About AJRR

The American Joint Replacement Registry (AJRR) is the cornerstone of the AAOS Registry Program. AJRR is overseen by the AJRR Steering Committee which reports to the Registry Oversight Committee and ultimately the AAOS Board of Directors with many stakeholders involved. As of June 30, 2019, the Registry now contains information on over 1.6 million procedures representing 8,786 surgeons and 1,284 institutions with data coming from hospitals, ambulatory surgery centers (ASCs), and private practice groups from all 50 states across the United States.

Our Vision

To be the National Registry for orthopaedics through comprehensive data and technology, resulting in optimal patient outcomes.
Data Quality and Sources

Data Reporting and Data Specifications
Since the beginning of AJRR, updating data specifications has been a necessary part of the process. Not only can specification updates improve the quality of data collected, but updates are made to reduce the data entry burden and ensure adaptation to changes in healthcare and the orthopaedic profession. A review of data elements collected at the time of this report can be found in Appendix A.

The last major update for AJRR’s data specification occurred in early 2017. This update resulted in significant improvements by providing further collection of procedural and post-operative. Moving forward, to simplify the transition and ensure routine enhancements, data specifications will be released and sunset on an annual basis. Specifically, the Annual Data Specification Sunset Cycle simplifies the transition of data specifications by informing users of when new ones will be released and older versions retired out.

On January 15 of each year starting in 2020, AAOS will release an updated data specification and data dictionary. From this date until June 15 of the same year, AAOS will support the three most recent versions of data specifications. During this time, Registry staff will work with all key stakeholders through educational efforts that include webinars, email articles, and informative updates communicating the changes made to the newest data specification. Finally, on June 15, AAOS will then retire the oldest of the three and support only the two latest versions.

In general, making updates to a data specification is a lengthy process. Every change, large or small, requires thorough review and vetting from multiple areas of AJRR leadership. This continuous process is ongoing throughout the year, ensuring perspectives from all involved parties are included.

CMS Data
A long-term priority for AJRR has been to obtain claims data from the Centers for Medicare & Medicaid Services (CMS) to facilitate linkages between AJRR and Medicare to support AJRR’s quality improvement and patient safety efforts. These linkages allow AJRR to obtain data including more complete comorbidity information, knowledge of revisions performed in non-AJRR institutions, and to fill-in data gaps where information was not submitted to AJRR. Following a detailed application process, this data was initially received from CMS on June 19, 2018. These files were updated again later that year to include data through 2017. In total, the CMS files include inpatient (148 data elements), outpatient...
Twelve of the provided data elements in CMS directly match AJRR data elements and can help fill in gaps in Registry information. Any additional data elements in CMS not in AJRR have been analyzed for completeness to be used in further analyses.

In summary, AJRR submitted a finder file with approximately 1.2M patient files to CMS and received 790,705 matching Medicare files including death information on over 26,359 AJRR patients from the National Death Index. The unmatched records were AJRR files on patients who were not Medicare participants and were either self-pay or covered by other payers. The last update provided information through the end of 2017. AJRR is in the process of obtaining 2018 files for future reporting and analysis.

Audit of Registry Data
The AAOS Registry Program and AJRR are committed to providing data reports that are valid and accurate. To ensure the Registry Program achieves this objective, internal quality controls are in place, in addition to an external audit of data from the previous year. The Registry randomly selected N=16 (2%), actively submitting AJRR sites, both hospitals and ambulatory surgery centers (ASCs), from January 1 to December 31, 2018 to participate. One site adjudicated during the 2018 audit and was required to participate this year, creating a total of 17 sites for the 2019 audit. The participating sites represented urban and rural locations, in addition to small and large institution size. Four of the randomly selected sites were issued waivers of exclusion based on personnel changes or electronic health record (EHR) transitions. As participation in the audit is mandatory, these four sites will be required to participate in the 2020 audit. One site was unable to submit data by the established deadline; this site was audited separately, and results were excluded from the aggregate summary. In total, 12 sites were included in the aggregate summary.

This year, none of the 12 sites requested adjudication of their results. The final overall audit agreement rate was 95.4%, which was slightly higher than the 94.5% overall audit agreement rate for 2018. The overall record completeness assessment rate was 93.0%, up from 75.0% last year. Formatting issues with reports submitted still remain a challenge for sites with respect to hindering completeness agreement rates. Most mismatches were found in documentation of laterality and hospital NPI. There were no anomalous observations to suggest any cherry picking or selection of only the best cases being submitted. It is important to understand this reflects agreement between the information in the hospital record and the information as reported to AJRR. The audit does not reflect whether data and resulting codes assigned in the hospital record were the most appropriate or accurate for the procedure performed. Efforts to address accuracy and appropriateness of the submitted data, especially at the point of data entry, will continue in collaboration with the participating hospitals. For more details about the Audit of Registry data, please see Appendix B.

AAOS Authorized Vendor Program
To minimize the data entry burden and enhance ease of data submission, AAOS has partnered with a vetted list of technological vendors through the Authorized Vendor Program. These top third-party electronic health record and user interface (UI) based technology vendors have made a commitment to prioritize data collection and submission by aiding sites in data collection, file configuration, and submission of procedure, post-operative, and patient-reported outcome (PRO) data.

As of June 2019, AAOS is currently engaged with dozens of vendors. For a complete list of authorized vendors please see Appendix C.
Recognizing the value of registries, in June of 2017 AAOS made a commitment to developing a family of registries across the spectrum of orthopaedic specialties. The first step was to bring AJRR into AAOS, making it the cornerstone of the AAOS Registry Program. Next, in 2018, was the addition of more registries including both procedural (Shoulder & Elbow Registry) and diagnosis-based (Musculoskeletal Tumor Pilot Registry) registries.

All registries receive governance from a Registry Oversight Committee that ultimately reports up to the AAOS Board of Directors.

**AAOS Registry Insights® 2019 Updates**

To provide further opportunities for surgeons and submitting facilities to utilize and analyze their data for quality improvement initiatives, an enhanced Registry Insights® platform was launched at the beginning of 2019. As part of the three-year technology enhancement roadmap, the updated user interface offers an improved user experience, benchmarking capabilities, and self-service analytics.

**Surgeon and Facility Dashboards**

Dashboards have been enhanced to allow users to gain more individual data insights. Surgeons whose sites participate in an AAOS Registry have access to a personalized dashboard and summarized status of their procedures. Facility administrators can also be provided a log-in to view aggregate facility-wide data. This is a no-cost benefit included in a site’s participation with AJRR. Surgeons and separate facility administrators can compare their aggregate data to de-identified national AJRR data for procedural, post-operative, and patient-reported outcome measures (PROMs) submissions. This side-by-side benchmarking can help to advance increased quality in patient care.

Registry Insights® reports enable surgeons and facilities to report to quality improvement initiatives, payer incentive programs, and performance measurement activities. Additionally, surgeons can earn up to 10 Self-Assessment Examination (SAE) credits for the American Board of Orthopaedic Surgery (ABOS) Maintenance of Certification (MOC) program with their access to Registry Insights® Surgeon Dashboards. For any aggregate analyses based off data submitted but not viewable on a dashboard, a custom report can be created upon request.

If you are a surgeon or site administrator who has submitted data to AJRR and would like either a Registry Insights® dashboard demo or help with dashboard enrollment, please contact RegistrySupport@aaos.org.
AJRR continues to build and enhance its collaborative relationships through strategic alliances and affiliations with other organizations, including:

**Advanced Medical Technology Association (AdvaMed)**
Medical device manufacturers provide ongoing financial support and continue to participate in the governance of AJRR via the Advanced Medical Technology Association Orthopedic Sector. This group nominates individuals to serve in the two Steering Committee positions designated for industry and, as requested, names individuals to serve on various committees where industry expertise or perspective is desired.

**Ambulatory Surgery Center Association (ASCA)**
In May 2019, AJRR and ASCA began a pilot program that provides the framework necessary for ASCs with low-volume and/or no technical capabilities. As the number of arthroplasty procedures performed in ASCs increases, it is important to capture data to understand efforts to improve quality, enhance practice efficiency, and reduce health care costs by groups migrating to this model of practice.

**American Association of Hip and Knee Surgeons (AAHKS)**
AJRR is the official registry of AAHKS with continued collaboration on numerous initiatives. AAHKS members receive information on joining the Registry, AJRR is given complimentary advertisements in AAHKS publications as well as on their website, and the AAHKS journal, *Arthroplasty Today*, is AJRR’s official journal. In 2019, AJRR has a poster and podium presentation based off Registry data at AAHKS’ Annual Meeting.

**American Hospital Association (AHA)**
AHA is the national organization that represents and serves all types of hospitals, health care networks, and their patients and communities. Historically, AHA has been a strong collaborative partner with medical associations, aiding in guideline development to improve quality and the level of recommendations provided. The AHA continues to collaborate with AJRR by maintaining a seat on the Steering Committee.

**International Society of Arthroplasty Registries (ISAR)**
ISAR is a global consortium of joint replacement registries established by several of the mature national registries. The society facilitates the development of registry science and observational studies, encourages the development of new national registries around the world, and provides a forum for information sharing to enhance participating countries’ ability to meet their own objectives. AJRR is proud to be an associate member of ISAR and the vendor for the International Protheses Library (IPL). In 2019, AJRR was well represented with presentations at the ISAR International Congress.

**National Association of Orthopaedic Nurses (NAON)**
NAON was incorporated in 1980 to advance the specialty of orthopaedic nursing through excellence in research, education, and nursing practice. Registry staff participated in the 2019 NAON National Congress and presented a lecture on starting a patient-reported outcomes program.

**Physician Clinical Registry Coalition (PCRC)**
This coalition is a group of 25 medical society-sponsored or physician-led clinical data registries working together to advocate for public policy changes to promote registry development and eliminate barriers. The coalition members work collaboratively to advocate for changes in legal and policy issues that are impeding the development and operations of clinical data registries or that could help facilitate and promote the growth of such repositories. AJRR has been an active member of this group since its inception.

**The Hip Society**
Founded in 1968, The Hip Society was created to advance the knowledge and treatment of hip disorders to improve the lives of patients. The Society shares such values as education, innovation and collaboration, integrity, inspiration, and achievement. It supports the discovery and dissemination of information specific to hip disorders. Membership to The Hip Society is through invitation only and several members also serve on AJRR committees. Members, aided by Registry staff, presented presentations based on AJRR data at The Hip Society meeting in the fall of 2019.

**The Knee Society**
The Knee Society was incorporated in 1983 to support the creation of a society for education and research in the area of total knee arthroplasty as well as in the pathogenesis of osteoarthritis and other disease processes that lead to end stage arthritis of the knee. Membership to The Knee Society is invitation only. Several members of The Knee Society also serve on AJRR committees. Members of The Knee Society had a presentation based on AJRR data at The Knee Society meeting in the fall of 2019.
2019 and Beyond

Over the past year, the AAOS Registry Program has been actively forging collaborations with a focus on minimizing the data entry burden and expanding opportunities for reuse of Registry data.

For a comprehensive list of all data reuse opportunities, please visit www.AAOS.org/registries here.

The Joint Commission Partnership
AAOS and The Joint Commission have announced a collaboration to oversee scientific issues, performance measures, quality improvement activities, education, data sharing, and research related to the Advanced Total Hip and Knee Replacement (THKR) Certification.

Effective July 1, 2019, AJRR became the sole pathway for meeting the THKR registry requirement.

NESTcc Grant
To minimize the data entry burden, the Registry continuously looks for ways to connect to external payer sources. One step in this direction was the acceptance of AAOS for the National Evaluation System for health Technology Coordinating Center (NESTcc) pilot grant. NESTcc is an initiative of the Medical Device Innovation Consortium (MDIC). AAOS is the only registry that was selected and will be representing the interest of our industry partners. This grant, Testing the Feasibility of Registry and Claims Data Linkages, will allow for feasibility testing around linkage with private payer data.

ABOS Maintenance of Certification (MOC)
The AAOS Registry Program has been approved by the American Board of Orthopaedic Surgery (ABOS) to support Maintenance of Certification. As of November 2018, a diplomate can receive Self-Assessment Credits (SAE) credits for each year of registry participation as an alternative to 10 scored and recorded SAE credits needed to satisfy ABOS MOC requirements.

AAOS Registry Analytics Institute™
Launched in February 2019, the AAOS Registry Analytics Institute™ allows for investigators with a well-defined hypothesis the opportunity to submit for access to Registry analytics. All submitted applications are first examined by the AAOS Registry Analytics team for feasibility. If feasible, members from the Research Projects Subcommittee complete a review to determine final decisions.

For more information on the AAOS Registry Analytics Institute™, please visit: https://www.aaos.org/Quality/Registry_Programs/AAOS_Registry_Analytics_Institute/

“The Academy’s commitment to maintain our position at the forefront of the quality movement is demonstrated by its ambitious initiative to create a family of orthopaedic registries. AJRR is the cornerstone of that effort and the model for creating new registries in other orthopaedic specialties, including the publication of reports such as this. The facilities and surgeons that participate in our registries should be very proud of their commitment to providing their data so we all can help improve orthopaedic outcomes in this country.”

William J. Maloney, MD
Chair, AAOS Registry Oversight Committee
Chair, Stanford University School of Medicine, Orthopaedic Surgery
On the Advocacy, Regulatory, and Quality Improvement Frontlines

AAOS continues to advocate for greater Registry participation and impact. One of the major barriers to the success of the Registry stems from regulatory issues surrounding data sharing and security. Many activities have been undertaken this year to facilitate greater engagement and promotion of the important work being conducted by AJRR.

Some of these activities include:

- AAOS advocates for the inclusion of clinical data registries as an effective mechanism for reducing such regulatory and administrative burden, while improving health outcomes. In January 2019 AAOS submitted comments to a Proposed Rule by the Department of Health and Human Services (HHS) on a national *Strategy on Reducing Regulatory and Administrative Burden Relating to the Use of Health IT and EHRs.*

- In February 2019, AAOS submitted comments to a Request for Information by the Office for Civil Rights (OCR) within HHS on *Modifying HIPAA Rules to Improve Coordinated Care.* Comments centered on re-assessing burdensome HIPAA requirements and opportunities to streamline regulations to improve the ability for clinical data registries to enhance patient care, improve quality, assess clinical performance, and provide timely feedback to clinicians.

- AAOS submitted comments to two Proposed Rules (one by Centers for Medicare & Medicaid Services (CMS) and one by the Office of the National Coordinator for Health IT) in June of 2019 on *improving interoperability and reducing information blocking.* AAOS comments focused on the current siloed electronic health information landscape and advocated for improvements that would help facilitate greater data exchange within the healthcare community.

- In August 2019, AAOS submitted comments to a Request for Information by CMS on *Reducing Administrative Burden to Put Patients Over Paperwork.* AAOS comments emphasized the importance of allowing eligible clinicians who use a certified electronic health record (EHR) and participate in a clinician-led Qualified Clinical Data Registry (QCDR) to qualify to achieve full credit and points in the Promoting Interoperability category of the Quality Payment Program’s (QPP’s) Merit Based Incentive Payment System (MIPS) program.

- AAOS submitted comments in September 2019 to the CMS annual Proposed Rule on the Quality Payment Program. The rule proposes several changes to the QCDR program that include new requirements for QCDRs and have *significance for clinician reporting* through QCDRs now and in the immediate future.

- AAOS continues to enhance their engagement with CMS and recently partnered to provide *AJRR data collection and to support alternative reporting starting in 2021 for the Bundled Payments for Care Improvement Advanced (BPCI Advanced) Model* within the Centers for Medicare & Medicaid Innovation (CMMI).

- AAOS consistently seeks out avenues for the *safe harbor protection of registry data* and has worked with the Physician Clinical Registry Coalition (PCRC) to maintain this as an advocacy priority.

“Surgeon Dashboards add value to quality improvement efforts in my practice. Specifically, it allows me to review my cases with a growing list of statistics and analytics. Through the dashboards, I have access to national benchmarks and averages for the procedures I am performing. It allows me to apply the platform’s interactive abilities to filter by patient and case type, and identify important practice changes that will benefit my patients going forward.”

Kieran Cody, MD
Orthopaedic Surgeon
Doylestown Hospital
Governance and Structure

In October 2017, AJRR was re-integrated back into AAOS and became the cornerstone of the AAOS Registry Program. Prior to this, AJRR was an independent 501(c)3 non-for-profit corporation with an independent Board of Directors. Once re-integrated, AJRR Board of Directors was transitioned to the AJRR Steering Committee and continues to maintain a multi-stakeholder model. This involves representation from key stakeholders involved in providing arthroplasty care including: patients, facilities, surgeons, device manufacturers, commercial health plan payers, and public individuals.

Many of the original surgeon leaders on the Steering Committee have been involved AJRR since the beginning. Their valuable service provided Registry knowledge needed to ensure a smooth transition into AAOS. The addition of members of the public has been pivotal to the success of the Registry. Their voices are included through the Public Advisory Board which allows for the inclusion of the patient perspective in all aspects of Registry governance.

2019 AAOS Registry Oversight Committee

Overseeing the Steering Committee is the Registry Oversight Committee (ROC). The ROC reports to the AAOS Board of Directors and provides guidance and recommendations for all major Registry initiatives.

The Registry Oversight Committee is led by the following orthopaedic surgeons:

**William J. Maloney, MD, Chair**
Stanford University (Stanford, CA)

**Kevin J. Bozic, MD, MBA**
Dell Medical School at The University of Texas at Austin (Austin, TX)

**Michael J. Gardner, MD**
Stanford University (Redwood City, CA)

**Steven D. Glassman, MD**
Norton Leatherman Spine Center (Louisville, KY)

**David A. Halsey, MD**
Martha’s Vineyard Hospital (Oak Bluffs, MA)

**David S. Jevsevar, MD, MBA**
Dartmouth-Hitchcock Medical Center (Lebanon, NH)

**Ronald A. Navarro, MD**
Kaiser Permanente South Bay Medical Center (Harbor City, CA)

**Kurt P. Spindler, MD**
Cleveland Clinic (Lyndhurst, OH)

**Gerald R. Williams Jr., MD**
The Rothman Institute (Philadelphia, PA)
2019 AJRR Steering Committee

Kevin J. Bozic, MD, MBA, Chair
AJRR Representative
Dell Medical School at The University of Texas at Austin (Austin, TX)

Bryan D. Springer, MD, Vice Chair
AAHKS Representative
OrthoCarolina (Charlotte, NC)

Scott M. Sporer, MD, Secretary
AAOS Representative
Midwest Orthopaedics at Rush (Chicago, IL)

David E. Mino, MD, MBA, Treasurer
Health Plan Representative
Cigna (Washington Crossing, PA)

David D. Lewallen, MD, Ex-Officio
AJRR Medical Director
Mayo Clinic (Rochester, MN)

James R. Banks, Member
Industry Representative
Stryker Howmedica Osteonics (Allendale, NJ)

James A. Browne, MD, Member
The Knee Society Representative
University of Virginia (Charlottesville, VA)

James I. Huddleston, III, MD, Member
California State Registry Committee Representative
Stanford University (Woodside, CA)

Robert L. Krebbs, Member
Health Plan Representative
Anthem, Inc. (Richmond, VA)

Gregory B. Krivchenia II, MD, Member
AAOS Representative
First Settlement Orthopaedics (Marietta, OH)

Brian S. Parsley, MD, Member
AAHKS Representative
University of Texas Health Science Center at Houston and Baylor College of Medicine (Houston, TX)

Richard F. Seiden, Esq., Member
Patient/Public Representative
(Manhattan Beach, CA)

James D. Slover, MD, MS, Member
The Hip Society Representative
NYU Langone (New York, NY)

Paul Voorhorst, Member
Industry Representative
DePuy Synthes (Warsaw, IN)

AJRR Committees

Many volunteers contribute to the success of the Registry. These individuals devote countless hours and devotion ensuring the Registry is of the highest possible quality. Below is a description of all AJRR Registry committees. Full membership can be found in Appendix D.

California State Registry Committee

Members of the California State Registry Committee conduct clinical affairs and make decisions that support the mission of AJRR and California state-related activities. Activities include data collection and review, public reporting of its findings, coordinating programs with third-party payers, and presentations at national and international meetings.

Chair: James I. Huddleston, III, MD

Data Management Committee

The Data Management Committee is responsible for recommendations to the Steering Committee concerning data elements to be included in the Registry and the methods by which the selected data are analyzed and reported. The committee is also responsible for recommendations concerning proposed analytical projects. Annually, the committee will submit a report to the AJRR Commission to validate the findings of the Data Management Committee.

Chair: Bryan D. Springer, MD

The Three Data Management Subcommittees are:

Data Elements and Analysis Subcommittee

This subcommittee monitors, receive requests, and makes recommendations for additions or deletions to data elements or assessment tools collected by AJRR. The subcommittee makes recommendations to the Data Management Committee for review prior to discussion and final approval by the AJRR Steering Committee. This subcommittee works with staff and statisticians to determine, develop, and oversee the implementation of appropriate data analysis methodology and algorithms. The subcommittee’s purview includes risk adjustment, scientific integrity of data, rigor of conclusions drawn from Registry data, and consideration of optimal reporting and data analysis to provide actionable data for the benefit of patients and other AJRR stakeholders.

Chair: Scott Sporer, MD

Publications Subcommittee

In 2019, recognizing a need to have AJRR representatives review and ensure the integrity of all publications based on Registry data, the Publications Subcommittee was formed. Publications for review include potential abstracts,
manuscripts, quarterly or special reports, as well as the Annual Report. The original Annual Report Subcommittee was rolled into the Publications Subcommittee and is one of the final signoffs on the completed Annual Report prior to the document being sent to the Commission and subsequently AJRR’s Steering Committee for their review. Chair: James A. Browne, MD

Research Projects Subcommittee
Members of the Research Projects Subcommittee review incoming external research proposals and requests and make recommendations for project approvals. The committee developed and now maintains the AAOS Registry Analytics InstituteTM, which launched in February 2019. Members provide guidance for the process and grading of submitted proposals. Chair: Richard L. Illgen II, MD

AJRR Commission
Established in 2014, the AJRR Commission is a group of six arthroplasty specialist orthopaedic surgeons without relevant financial conflicts who serve as independent reviewers of the data published in this Annual Report. The Commission makes the final recommendation to the Steering Committee regarding the content of the Annual Report. The Commission members are known only to the Steering Committee to ensure members’ independence and allow them to avoid undue outside influence pertaining to the report.

Public Advisory Board
The Public Advisory Board (PAB) provides direct input to the Steering Committee from both the patient and public perspective. The PAB members are drawn from a wide variety of public advocacy groups and members of the public who have had joint arthroplasties themselves. Chair: Margaret VanAmringe, MHS (term ended 6/30/19), Richard F. Seiden, Esq. (term began 7/1/2019)

Outgoing 2018 Volunteers
AJRR would like to express its gratitude and appreciation for the contributions made by all of our volunteers. The Registry would like to specifically recognize the work of the following volunteers whose terms concluded in 2019.

AJRR Steering Committee
Daniel J. Berry, MD
Mayo Clinic (The Hip Society) (Rochester, MN)
Yvonne Bokelman, MBA, FACHE
ZimmerBiomet, Inc. (Industry Observer) (Warsaw, IN)
Kristen Murtos, MBA
NorthShore Skokie Hospital (American Hospital Association) (Skokie, IL)
Douglas E. Padgett, MD
Hospital for Special Surgery (AAOS Representative) (New York, NY)
Margaret VanAmringe, MHS
The Joint Commission (Public Representative) (Washington, DC)

Public Advisory Board:
John A. Canning Jr. (Chicago, IL)
Mark Haubner (Aquebogue, NY)
Margaret VanAmringe, MHS (Washington, DC)

User Group Network
The User Group Network (Unet) brings a participant perspective to Registry leadership and provides a peer group for all submitting participants. AJRR would like to extend appreciation to the following participants for their specific leadership by serving on the Unet Advisory Board:

Patrice Hallak
Providence Health & Services (Renton, WA)
Christina Kane EdD, MS, OTR
Catholic Health (Buffalo, NY)
Amy Ketchum MS, RN, OCNS-C
Midwest Orthopedic Specialty Hospital (Franklin, WI)
Mark A. Snyder, MD
TriHealth Orthopedic Sports Institute (Cincinnati, OH)
Cheryl Talamo, PT, MPT
Doylestown Hospital (Doylestown, PA)
Industry Collaborations

AJRR recognizes the importance of device surveillance and collecting quality data to improve outcomes. The Registry works with sites and manufacturers to understand how implants contribute to patient experience and quality of life. The AJRR multi-stakeholder model allows for providers and companies to evaluate poorly performing implants based on national trends of longitudinal patient data.

“Through my work on various AJRR leadership committees, I am well aware of the many ways AJRR participant sites can benefit from the registry’s rapidly expanding opportunities to utilize robust data. These opportunities include assistance in meeting requirements for quality certification programs, federal quality initiatives, insurer’s distinction programs, and state collaboratives. Hospitals, ambulatory surgery centers, and surgeons need to be aware of current and emerging data opportunities to maximize registry participation and improve patient outcomes.”

Bryan D. Springer, MD
Vice Chair, AJRR Steering Committee
Chair, AJRR Data Committee
OrthoCarolina Hip and Knee Center
Overall Results

Procedural Data Metrics

The 2019 American Joint Replacement Registry Annual Report represents 1,525,435 primary and revision hip and knee arthroplasty procedures performed between 2012 and 2018 (Figure 1.1). Primary knee (55.1%) and primary hip (33.1%) procedures made up the majority (Figure 1.2). Sex breakdown was 59.0% female and 41.0% male for all cases (Figure 1.3). The average age of a hip arthroplasty patient was 67.4 years and 66.7 years for all knee cases.

The 2019 Annual Report had an overall cumulative procedural volume growth of 28.5% compared to 2018.
Most of the patients in the data were white (72.1%) although race was not recorded in 18.7% of cases (Figure 1.4).

AJRR accepts historical data back to 2012. Therefore, annual volumes from prior years are continually being updated. When comparing the 2018 Annual Report to 2019, the procedures reported to have occurred in 2017 grew by over 5.8%. In general, the 2019 Annual Report had an overall cumulative procedural volume growth of 28.5% compared to 2018. This dataset represents a snapshot of AJRR data taken on June 3, 2019.

**Figure 1.4 Race of Patients Undergoing Procedures, 2012-2018 (N=1,525,435)**

*Invalid implies unusable data submitted to AJRR

<table>
<thead>
<tr>
<th>Race</th>
<th>Count (n)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>1,099,192</td>
<td>72.1%</td>
</tr>
<tr>
<td>Not Recorded</td>
<td>285,940</td>
<td>18.7%</td>
</tr>
<tr>
<td>Black or African American</td>
<td>76,626</td>
<td>5.0%</td>
</tr>
<tr>
<td>Two or More</td>
<td>21,257</td>
<td>1.4%</td>
</tr>
<tr>
<td>Invalid</td>
<td>19,117</td>
<td>1.3%</td>
</tr>
<tr>
<td>Asian</td>
<td>15,134</td>
<td>1.0%</td>
</tr>
<tr>
<td>American Indian</td>
<td>6,977</td>
<td>0.5%</td>
</tr>
<tr>
<td>Native Hawaiian</td>
<td>1,192</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

**Submitting Facilities**

Since inception, facility enrollment and data submission has been a major priority including growth in the number of hospitals, ambulatory surgery centers (ASCs), and private practice groups submitting data to the Registry. As of June 30, 2019, enrollment included 1,133 hospitals, 104 ASCs, and 65 private practice groups contracted to submit data to AJRR from across all 50 states and the District of Columbia. California facilities had the most contracted at 135, followed by Florida (84) and Texas (83). Five other states had more than 50 (Illinois, Wisconsin, Ohio, Pennsylvania, and New York). In 2018, 1,219 facilities were enrolled to submit data to AJRR (Figure 1.5). A list of all enrolled facilities and those that submitted data used in the 2019 Annual Report can be found in Appendix E.

AJRR has no requirements on frequency of data submission but recommends as a best practice at least quarterly. In addition to increasing facility enrollment, the Registry is focused on promoting active data submission. To help with this, the Registry has a Registry Support Team and Support Specialists to expedite submissions and minimize data submission burden.

**Figure 1.5 Facility Enrollment by Year, 2011-2018***

*As of June 30, 2019, enrollment included 1,133 hospitals, 104 ASCs, and 65 private practice groups contracted to submit data to AJRR from across all 50 states and the District of Columbia.*
Ambulatory Surgery Centers

Ambulatory surgery centers (ASCs) continue to revolutionize outpatient care. While historically, much of the procedural information in the registry has come from hospitals, the number of arthroplasties performed in outpatient settings continues to rise. Considering this, AAOS understands the need to capture information from ASCs and private practices so these facilities have access to data quality, analysis, and benchmarking. In late 2018, AAOS took the first steps toward growing its ASC representation by restructuring the engagement team. To best serve these institutions, a focus was made on the active recruitment, education, and engagement of ASCs. The strategic refocus has been successful, as the number of ASCs participating in the Registry rose from 75 to 104 between July 1, 2018 and August 1, 2019, which represents a 38.7% growth (Figure 1.8).

Similar to past years, the majority of arthroplasty procedures submitted to the Registry were performed in medium-sized hospitals (43.7%) and minor teaching institutions (40.9%) (Figures 1.6 and 1.7). Non-teaching institutions were close behind minor teaching institutions at 36.9%. Of those with institutional data in the American Hospital Association survey, major and minor teaching hospitals accounted for 53.1% of all AJRR submitting hospitals.

The number of ambulatory surgery centers (ASCs) participating in the Registry rose from 75 to 104 over the past year which represents a 38.7% growth in participation.

**Figure 1.6** Hospital Size (Bed Count) of Submitting Hospitals, 2012-2018 (N=821)*

**Figure 1.7** Teaching Affiliation of Submitting Hospitals, 2012-2018 (N=821)*

**Figure 1.8** Ambulatory Surgery Centers Total Enrollment by Year, 2012-2018*

*Not all participating hospitals had relevant data submitted in the AHA survey.
An ASC is classified by a submitting institution on their AJRR application and can be either freestanding or affiliated with a hospital. The number of procedures submitted by ASCs has grown exponentially between 2012 (n=5) and 2018 (n=4,993) (Figure 1.9).

![Figure 1.9 Ambulatory Surgery Centers Cumulative Volume by Year, 2012-2018 (N=4,993)](chart)

**Figure 1.9** Ambulatory Surgery Centers Cumulative Volume by Year, 2012-2018 (N=4,993)

**Figure 1.10** Cumulative Number of Surgeons Represented in Annual Procedure Submissions by Year, 2012-2018 (N=8,509)

**Submitting Surgeons**

AJRR submitting institutions report data for an average of 13.8 surgeons (range 1-319). These numbers include surgeons that have done at least one arthroplasty procedure. As part of the contract, AJRR participating hospitals are required to submit data from all surgeons conducting hip or knee joint arthroplasty procedures at their facility. This is validated by annual audits (See Appendix B). As of now, 4,206 surgeons have submitted at least one procedure in 2018 (Figure 1.10). As AJRR accepts historical data and many institutions submit towards the end of the following year, it is anticipated that the 2018 numbers will grow substantially by next year’s Annual Report.

**INSIGHTS**

4,206 surgeons have submitted at least one procedure in 2018 to AJRR.
Data Completeness

Making updates to a data specification is a lengthy process. Understanding how data is submitted to the Registry and what percentage has acceptable values can help guide these updates. In February 2017, AJRR significantly expanded on the elements being collected to include procedural data, patient risk factors and comorbidities, and operative and perioperative complications. To allow time for participants to adjust to the additions, these changes were not made mandatory until January 1, 2018. Elements that can automatically be extracted from an electronic health record (EHR), such as discharge disposition and length of stay, tend to have higher data completeness (Table 1.1). Other elements that require more manual submission are more difficult to submit. While surgical technique for hip and knee were both part of the update, they have still proven to be difficult to collect. This has been discussed at length with members of the Registry Analytics team and AJRR leadership. Updates for both elements are planned in the next data specification release. For many elements, “not reported” or “NR” is an accepted value.

Table 1.1 Completeness of AJRR Data Elements, 2012-2018 (N=1,525,435)

<table>
<thead>
<tr>
<th>Data Elements</th>
<th>% of Cases with Accepted Value</th>
<th>% of Cases with Missing Value</th>
<th>% of Cases with Invalid Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Birth</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Sex</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Race</td>
<td>98.70%</td>
<td>0.00%</td>
<td>1.30%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>99.10%</td>
<td>0.00%</td>
<td>0.90%</td>
</tr>
<tr>
<td>City</td>
<td>88.40%</td>
<td>11.60%</td>
<td>0.00%</td>
</tr>
<tr>
<td>State</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>First Implant Catalog # Listed</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Implant Lot #</td>
<td>93.10%</td>
<td>6.90%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Unique Device Identification (UDI)</td>
<td>31.50%</td>
<td>68.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Procedure Date</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Principal Diagnosis Code</td>
<td>90.10%</td>
<td>0.00%</td>
<td>9.90%</td>
</tr>
<tr>
<td>Laterality</td>
<td>99.70%</td>
<td>0.10%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Procedure Site</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Body Mass Index (BMI)*</td>
<td>91.40%</td>
<td>0.00%</td>
<td>8.60%</td>
</tr>
<tr>
<td>Comorbidity - at least one comorbidity code reported*</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Anesthesia Type*</td>
<td>97.00%</td>
<td>1.50%</td>
<td>1.40%</td>
</tr>
<tr>
<td>Computer Navigation (Y/N)*</td>
<td>Y - 3.4%</td>
<td>95.6%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>N - 95.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robotic Assisted (Y/N)*</td>
<td>Y - 3.3%</td>
<td>95.8%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>N - 95.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical Approach*</td>
<td>61.00%</td>
<td>1.90%</td>
<td>37.70%</td>
</tr>
<tr>
<td>Periarticular Injection*</td>
<td>99.10%</td>
<td>0.00%</td>
<td>0.90%</td>
</tr>
<tr>
<td>Discharge Disposition*</td>
<td>99.10%</td>
<td>0.00%</td>
<td>0.90%</td>
</tr>
<tr>
<td>Length of Stay*</td>
<td>98.20%</td>
<td>1.70%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Procedure Duration*</td>
<td>98.10%</td>
<td>1.70%</td>
<td>0.20%</td>
</tr>
</tbody>
</table>

*Data element collection started in February 2017
Component attributes are defined by an internally managed AJRR component database, cross-referenced with the International Prosthesis Library (IPL), and have been collected since the beginning of AJRR (Tables 1.2 and 1.3).

**Table 1.2** Completeness of Selected Component Attributes – Hip, 2012-2018

<table>
<thead>
<tr>
<th>Component</th>
<th>% Cases with Accepted Value</th>
<th>% of Cases with Attribute Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity</td>
<td>99%</td>
<td>1%</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>57%</td>
<td>43%</td>
</tr>
<tr>
<td><strong>Acetabular Liners</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composition of the Polyethylene</td>
<td>95%</td>
<td>5%</td>
</tr>
<tr>
<td>Inside Diameter</td>
<td>91%</td>
<td>9%</td>
</tr>
<tr>
<td>Outside Diameter</td>
<td>65%</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Acetabular Shells</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside Diameter</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td><strong>Femoral Stem</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement Fixation</td>
<td>94%</td>
<td>6%</td>
</tr>
<tr>
<td>Size of Component Specified</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Component Length Specified</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td><strong>Femoral Head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal vs. Ceramic Composition</td>
<td>88%</td>
<td>12%</td>
</tr>
<tr>
<td>Head Diameter</td>
<td>99%</td>
<td>1%</td>
</tr>
</tbody>
</table>

**Table 1.3** Completeness of Selected Component Attributes – Knee, 2012-2018

<table>
<thead>
<tr>
<th>Component</th>
<th>% of Cases with Accepted Value</th>
<th>% of Cases with Attribute Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Femoral Component</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement Fixation</td>
<td>72%</td>
<td>28%</td>
</tr>
<tr>
<td><strong>Patellar Component</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement Fixation</td>
<td>82%</td>
<td>18%</td>
</tr>
<tr>
<td><strong>Tibial Component</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement Fixation</td>
<td>85%</td>
<td>15%</td>
</tr>
</tbody>
</table>

“The American Academy of Orthopaedic Surgeons is the world’s preeminent provider of musculoskeletal education, and the close working relationship we will maintain with the AJRR offers powerful opportunities to strengthen our quality measurement and quality improvement activities. Formalizing The Joint Commission’s work with AAOS ensures that our combined expertise will positively affect orthopaedic care for years to come.”

David Baker, MD  
Executive Vice President,  
Division of Healthcare Quality Evaluation  
The Joint Commission
Hip Arthroplasty

Hip Overview

Between 2012 and 2018, AJRR has collected data on 602,582 hip arthroplasty procedures. The majority of surgeons with data in AJRR perform both elective primary total hip arthroplasties and hemiarthroplasty for fracture. For those surgeons performing elective primary total hip arthroplasty procedures, the mean procedure count was 32 (range=1-838 procedures) with an interquartile range (25th-75th percentile) of 2-39 procedures (Table 2.1). The per surgeon median is lower, suggesting a higher frequency of lower volume surgeons in the Registry. These volumes are similar to that reported in 2010 by Bozic et al. Only surgeons with at least one relevant hip procedure were included.

Table 2.1 Average Procedural Volume for Participating Surgeons, 2018 (N=4,102)*

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Total Surgeons</th>
<th>Total Procedures</th>
<th>Per Surgeon Mean</th>
<th>Per Surgeon Median</th>
<th>Interquartile Range (25th percentile - 75th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Primary Total Hip Arthroplasty</td>
<td>2,911</td>
<td>93,122</td>
<td>32.0</td>
<td>13</td>
<td>2-39</td>
</tr>
<tr>
<td>Total Hip Arthroplasty for Fracture</td>
<td>966</td>
<td>2,277</td>
<td>2.4</td>
<td>1</td>
<td>1-2</td>
</tr>
<tr>
<td>Hemiarthroplasty for Fracture</td>
<td>2,499</td>
<td>6,884</td>
<td>2.8</td>
<td>1</td>
<td>1-3</td>
</tr>
<tr>
<td>Revision Hip Arthroplasty</td>
<td>1,279</td>
<td>4,336</td>
<td>3.4</td>
<td>2</td>
<td>1-4</td>
</tr>
<tr>
<td>Hip Resurfacing</td>
<td>45</td>
<td>388</td>
<td>8.6</td>
<td>3</td>
<td>1-5</td>
</tr>
</tbody>
</table>

*Procedures for conversion of previous non-arthroplasty hip surgery to total hip arthroplasty were excluded.

The categories for hip procedures remained relatively constant as a percentage of all hip procedures performed in 2018 (Figure 2.1). The “other procedures” category includes procedures such as arthrotomy and conversion from prior hip surgery.
The mean age for patients undergoing an elective total hip arthroplasty was 65.6 years. While hip resurfacing is reported infrequently in the AJRR, the population is younger with an average age of 53.4 years (Table 2.2, Figure 2.2).

### Table 2.2 Mean Age of Patients Undergoing Hip Arthroplasty Procedures, 2012-2018 (N=597,258)

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Mean Age (Years)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemiarthroplasty for Fracture</td>
<td>80.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Total Hip Arthroplasty for Fracture</td>
<td>72.4</td>
<td>12.4</td>
</tr>
<tr>
<td>Revision Hip Arthroplasty</td>
<td>67.3</td>
<td>12.9</td>
</tr>
<tr>
<td>Elective Primary Total Hip Arthroplasty</td>
<td>65.6</td>
<td>11.4</td>
</tr>
<tr>
<td>Hip Resurfacing</td>
<td>53.4</td>
<td>8.9</td>
</tr>
</tbody>
</table>

When evaluating mean length of stay in the AJRR cohort, there was a statistically significant decrease of over 0.5 a day when comparing mean length of stay for elective primary total hip arthroplasties from 2012 (2.6 (95% CI, 2.6-2.7)) to 2018 (1.9 (95% CI, 1.8-1.9)). Although there was also a trend towards decreased length of stay in patients with a fracture treated with total hip arthroplasty or hemiarthroplasty, it was not statistically significant (Figure 2.3). For this analysis, length of stay was calculated by subtracting admission date from discharge date and adding one.

*Upper and lower confidence limits for elective primary total hip arthroplasty in 2015 were equal to 2.2.*

INSIGHTS

Mean length of stay decreased by over 0.5 a day day when comparing elective total hip arthroplasties from 2012 to 2018.
Arthroplasty for Femoral Neck Fracture

Between 2012 and 2018, AJRR has collected data on 49,143 hip arthroplasty procedures for femoral neck fracture.

In the AJRR population, displaced femoral neck fractures (FNF) are commonly treated with either hemiarthroplasty or total hip arthroplasty (THA). Options for treatment still remains debated.3 Given that AJRR only collects arthroplasty procedures, patients treated with open reduction and internal fixation (ORIF) are not included. While historically AJRR has seen hemiarthroplasty predominate as the most frequent arthroplasty option for FNF, there has been a significant decrease in its use compared to THA between 2013 and 2018 (p<0.0001) (Figure 2.4). This finding is consistent with reports from other national registries.4,5 In AJRR, for patients <60 years of age, THA was the treatment of choice for displaced FNF. This switches at age ≥60 years, where hemiarthroplasty becomes preferred and >70 years of age becomes the predominant option (Figure 2.5).

Figure 2.4 Total Hip Arthroplasty and Hemiarthroplasty Performed for the Diagnosis of Femoral Neck Fracture, 2012-2018 (N=59,131)

Figure 2.5 Percentage of Total Hip Arthroplasty and Hemiarthroplasty for Treatment of Femoral Neck Fractures by Age Group, 2012-2018 (N=59,131)

In AJRR, for patients <60 years of age, THA was the treatment of choice for displaced FNF, but at age ≥60 years, hemiarthroplasty becomes preferred and is the predominant option for patients >70.
Both cemented and cementless fixation for femoral stems are frequently used in the treatment of femoral neck fractures. Cemented fixation was more commonly utilized for hemiarthroplasty than total hip arthroplasty (Figure 2.6). While AJRR saw an increase in cementless stem use through 2016, this appears to have peaked in 2016 at 61.3%, and has been declining over the past two years (p<0.0001).

**Figure 2.6** Cemented Fixation for Femoral Stems in Total Hip Arthroplasty and Hemiarthroplasty for Femoral Neck Fracture, 2012-2018 (N=15,712)

Cemented femoral component fixation for the treatment of FNF was more commonly utilized for hemiarthroplasty than total hip arthroplasty. AJRR saw an increase in cementless femoral component fixation for the treatment of FNF through 2016, however, this appears to have peaked in 2016 at 61.3%, and has been declining over the past two years.

**INSIGHTS**

Cemented femoral component fixation used in hemiarthroplasty for the treatment of FNF increased in utilization with each advancing decade of life (Figure 2.7). In contrast to the majority of international registries, however, <50% of the oldest age group received cemented stems. 6-8 Internationally, cemented femoral stem fixation for femoral neck fractures still predominates; in 2018, the National Joint Registry and Swedish Hip Arthroplasty Register reported that 22.3% and just over 2% (respectively) of all stems used to treat femoral neck fractures were cementless. 7,8

**Figure 2.7** Percent of Cemented Stem Fixation Used in Hemiarthroplasty for Femoral Neck Fracture by Age Group, 2012-2018 (N=14,229)
For all hemiarthroplasty procedures to treat femoral neck fracture, unipolar heads were used in 44.5% of all cases in 2018 (Figure 2.8). Similar to previous AJRR Annual Reports, the use of unipolar heads increased with each additional decade of life (Figure 2.9).

### Hip Resurfacing

**Between 2012 and 2018, AJRR has collected data on 5,183 hip resurfacing procedures.**

Hip resurfacing as a percentage of the total number of elective hip arthroplasty procedures submitted to AJRR continues to decline due to the diminished use of metal-on-metal articulations (Figure 2.10). In 2018, a total of 45 surgeons performed the 387 hip resurfacing procedures. Of these procedures, 72.0% were performed by six surgeons and 25.3% performed by a single surgeon.

**Figure 2.10** Hip Resurfacing as a Percentage of Elective Hip Arthroplasty Procedures by Year, 2012-2018 (N=5,183)*

*Elective hip arthroplasty procedures defined as both elective primary total hip and resurfacing arthroplasty procedures.
Elective Primary Total Hip Arthroplasty

Between 2012 and 2018, AJRR has collected data on 486,772 elective primary total hip arthroplasty procedures. Similar to previous AJRR Annual Reports, more than half of patients ≤59 years of age undergoing elective primary total hip arthroplasty were male. After the age of 60, females predominate and this trend increases with each additional decade of life (Figure 2.11).

Since 2012, AJRR data has shown an increase in usage of 36mm heads and an overall decrease in 32mm femoral heads in elective primary total hip arthroplasty procedures (p<0.0001). Larger (≥40mm) head size usage has stabilized and smaller (<28mm) is slightly decreasing. The use of dual mobility articulations in both primary and revision hip arthroplasty as reported to AJRR continues to increase (Figure 2.12).

The use of dual mobility articulations in both primary and revision hip arthroplasty as reported to AJRR continues to increase.

*Constrained implants excluded.
After adjusting for age and sex for patients ≥65 years of age as reported to either AJRR or CMS, 36mm head diameters showed better survival compared to ≤28mm (HR=1.584, 95% CI, 1.298-1.934, p<0.0001) (Figure 2.13). However, this difference was small, there were far fewer ≤28mm femoral heads used and this does not account for other potential confounders.

**Figure 2.13** Diameter of Femoral Heads for Elective Primary Total Hip Arthroplasty in Patients >65 Years of Age with Primary Osteoarthritis and an Endpoint of Revision, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤28mm</td>
<td>993</td>
<td>1,390</td>
<td>1,024</td>
<td>629</td>
<td>450</td>
<td>95</td>
</tr>
<tr>
<td>32mm</td>
<td>12,544</td>
<td>14,628</td>
<td>12,342</td>
<td>8,490</td>
<td>4,771</td>
<td>1,358</td>
</tr>
<tr>
<td>36mm</td>
<td>32,924</td>
<td>34,387</td>
<td>26,543</td>
<td>17,065</td>
<td>8,229</td>
<td>2,177</td>
</tr>
<tr>
<td>≥40mm</td>
<td>3,081</td>
<td>3,164</td>
<td>2,780</td>
<td>1,819</td>
<td>1,040</td>
<td>385</td>
</tr>
</tbody>
</table>

HR = adjusted for age and sex

≤28mm vs. 36mm: Entire Period HR=1.584 (95% CI, 1.298-1.934) p<0.0001
32mm vs. 36mm: Entire Period HR=0.986 (95% CI, 0.901-1.079) p=0.7585
≥40mm vs. 36mm: Entire Period HR=1.266 (95% CI, 1.091-1.469) p=0.0019
In 2018, 6.9% of all elective primary hip arthroplasty procedures utilized a dual mobility acetabular construct. AJRR saw a statistically significant increase in dual mobility usage for elective primary hip arthroplasty procedures when comparing 2012 to 2018 (p<0.0001). The increase in popularity may be explained by the perception of increased stability and reduced risk of dislocation. These constructs were used most commonly in the youngest (<50 years) and oldest (≥90 years) population (Figure 2.14).

After adjusting for age and sex as reported to AJRR for all ages, there was no difference in survivorship when comparing conventional femoral head usage to dual mobility for elective primary total hip arthroplasty procedures (HR=1.154, 95% CI, 0.966-1.379, P=0.1152) (Figure 2.15). When looking at patients ≥65 years of age as reported to either AJRR or CMS, there was improved survivorship with conventional femoral head usage (HR=1.302, 95% CI, 1.102-1.538, p=0.0019) (Figure 2.16). As previously noted, this represents association rather than causation and does not account for potential confounders, such as the patient’s risk of dislocation. 

**Figure 2.14** Dual Mobility Usage as a Percentage of All Elective Primary Total Hip Arthroplasty by Age Group, 2012-2018 (N=30,880)

**Figure 2.15** Survivorship of Dual Mobility Used for Elective Primary Total Hip Arthroplasty for Patients with Primary Osteoarthritis and an Endpoint of Revision as Submitted Only to AJRR, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Dual Mobility</td>
<td>95,183</td>
<td>107,866</td>
<td>88,027</td>
<td>61,581</td>
<td>30,430</td>
<td>7,381</td>
</tr>
<tr>
<td>Dual Mobility</td>
<td>7,230</td>
<td>6,180</td>
<td>3,483</td>
<td>2,029</td>
<td>1,109</td>
<td>348</td>
</tr>
</tbody>
</table>

HR: adjusted for age and sex

Dual Mobility vs. No Dual Mobility Articulation: Entire Period HR=1.154 (95% CI, 0.966-1.379), p=0.1152
After adjusting for age and sex, there was improved survivorship when comparing conventional femoral head usage to dual mobility for elective primary total hip arthroplasty procedures.
For all elective primary total hip arthroplasty procedures, ceramic head usage has continued to increase, while there has been a corresponding and statistically significant decrease in cobalt chromium (CoCr) usage (p<0.0001) (Figure 2.17). This increase in ceramic head usage may be attributed to the perception of favorable wear characteristics, their use as an alternative to metal-on-metal articulations, or the concerns of trunnion and taper corrosion seen with CoCr heads. These same factors likely play a role in the preference for ceramic heads in younger age groups where they are preferred until >72.0 years of age when CoCr predominates (Figure 2.18).

**Figure 2.17** Composition of Femoral Heads for All Elective Primary Total Hip Arthroplasty Procedures, 2012-2018 (N=414,119)

**Figure 2.18** Femoral Head Composition for All Elective Primary Total Hip Arthroplasty Procedures by Age Group, 2012-2018 (N=384,959)
For both cobalt chromium and ceramic heads used by surgeons in the AJRR cohort, highly cross-linked polyethylene was more commonly utilized compared to antioxidant polyethylene for all elective primary total hip arthroplasty procedures (Figures 2.19 and 2.20). There is also a trend toward increased antioxidant liner use with ceramic heads compared to CoCr heads on a yearly basis (p<0.0001). While cross-linked polyethylene is still the acetabular liner of choice for AJRR surgeons, antioxidant polyethylene use has been increasing over time (p<0.0001). The use of conventional polyethylene (UHMWPE) in the AJRR primary total hip arthroplasty cohort has become vanishingly small, dropping to <1.0% in 2018, as surgeons have almost entirely moved to either highly cross-linked or antioxidant polyethylene alternatives (Figure 2.21).

Figure 2.19 Percentage of Cobalt Chromium Heads Used with Cross-Linked Polyethylene and Antioxidant Polyethylene Acetabular Liners for All Elective Primary Total Hip Arthroplasty Procedures, 2012-2018 (N=184,214)

Figure 2.20 Percentage of Ceramic Heads Used with Cross-Linked Polyethylene and Antioxidant Polyethylene Acetabular Liners for All Elective Primary Total Hip Arthroplasty Procedures, 2012-2018 (N=233,287)

Figure 2.21 Percentage of Antioxidant Polyethylene Usage in Acetabular Liners by Year for All Elective Primary Total Hip Arthroplasty Procedures, 2012-2018 (N=473,507)
Cementless femoral component fixation for elective primary total hip arthroplasty dramatically outweighs the use of cemented fixation in the AJRR population. From 2012-2018, only 4.3% of all elective primary total hip arthroplasty procedures in AJRR utilized cemented femoral component fixation. When examining usage by age, there was a significant increase in cemented fixation with advancing age (p<0.0001) (Figure 2.22) and over time (p<0.0001) (Figure 2.23). However, the use of cemented femoral component fixation in the AJRR is still lower than that seen in international registries. The 2018 Annual Report for the National Joint Registry reported much higher use of cemented femoral component fixation across all age groups (34.2%). The Australian Orthopaedic Association National Joint Replacement Registry also reports a higher use of cemented fixation compared to AJRR, although the use of cementless stem fixation has been increasing from 51.3% in 2003 to 63.1% in 2017. In their 2017 Annual Report, the Swedish Hip Arthroplasty Register noted that the proportion of cemented prostheses in that year was 60%. They also commented that completely cementless fixation has been increasing from 2% in 2000 to 24% in 2017.

Figure 2.22 Cemented and Cementless Femoral Stem Fixation in Elective Primary Total Hip Arthroplasty by Age Group, 2012-2018 (N=451,382)

Figure 2.23 Cemented and Cementless Femoral Stem Fixation in Elective Primary Total Hip Arthroplasty, 2012-2018 (N=451,382)
When examining survivorship of cementless versus cemented femoral component fixation for patients ≥65 years of age as reported to either AJRR or CMS, cementless femoral components had higher survivorship when adjusting for age and sex (HR = 0.689, 95% CI, 0.606-0.783, p<0.0001) (Figure 2.24). Analysis of males and females separately suggests a more pronounced difference in survivorship for males ≥65 (Figure 2.25) than females ≥65 (Figure 2.26). It is important to note this does not account for potential confounders that were not examined.

Figure 2.24 Femoral Stem Fixation for Elective Primary Total Hip Arthroplasty 65 Years of Age with Primary Osteoarthritis Age and Sex Adjusted, 2012-2018*

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementless</td>
<td>43,776</td>
<td>49,390</td>
<td>39,987</td>
<td>26,457</td>
<td>13,782</td>
<td>3,800</td>
</tr>
<tr>
<td>Cemented</td>
<td>2,292</td>
<td>3,311</td>
<td>2,928</td>
<td>1,997</td>
<td>1,447</td>
<td>763</td>
</tr>
</tbody>
</table>

HR = adjusted for age and sex  
Cemented vs. Cementless: Entire Period HR = 0.689 (0.606-0.783), p<0.0001
**Figure 2.25** Femoral Stem Fixation for Elective Primary Total Hip Arthroplasty 65 Years of Age with Primary Osteoarthritis Age Adjusted for Males, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementless</td>
<td>18,245</td>
<td>20,129</td>
<td>16,540</td>
<td>11,048</td>
<td>5,659</td>
<td>1,532</td>
</tr>
<tr>
<td>Cemented</td>
<td>472</td>
<td>826</td>
<td>773</td>
<td>564</td>
<td>392</td>
<td>215</td>
</tr>
</tbody>
</table>

HR = adjusted for age
Cemented vs. Cementless: Entire Period HR=0.512 (0.411-0.638), p<0.0001
Figure 2.26 Femoral Stem Fixation for Elective Primary Total Hip Arthroplasty 65 Years of Age with Primary Osteoarthritis Age Adjusted for Females, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementless</td>
<td>25,518</td>
<td>29,241</td>
<td>23,430</td>
<td>15,397</td>
<td>8,118</td>
<td>2,265</td>
</tr>
<tr>
<td>Cemented</td>
<td>1,819</td>
<td>2,485</td>
<td>2,153</td>
<td>1,430</td>
<td>1,054</td>
<td>547</td>
</tr>
</tbody>
</table>

HR = adjusted for age
Cemented vs. Cementless: Entire Period HR=0.774 (0.663-0.904), p=0.0012
For the first time with this year’s *AJRR Annual Report*, various analyses were performed to better understand the association of patient comorbidity and survivorship following total hip arthroplasty. Smoking was one comorbidity that was analyzed. An association was seen between the presence of an administrative code for current or former smoking and decreased survivorship of an elective primary total hip arthroplasty in patients ≥65 years of age as reported to either AJRR or CMS. After adjusting for age and sex, current smoking status was associated with a rate of revision 1.52 times that of patients who have never smoked (HR=1.52, 95% CI, 1.225-1.881, p=0.0001) (Figure 2.27). This must be interpreted in light of the limitations with administrative coding of smoking status and any potential confounders that remain unexamined.

**Figure 2.27** Smoking Status and Survivorship for Elective Primary Total Hip Arthroplasty for Patients >65 Years of Age with Primary Osteoarthritis and an Endpoint of Revision, 2012-2018*

*For survivorship methodology see Appendix F*

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never Smoked</td>
<td>57,897</td>
<td>56,624</td>
<td>44,219</td>
<td>29,050</td>
<td>15,555</td>
<td>4,208</td>
</tr>
<tr>
<td>Current Smoker</td>
<td>219</td>
<td>381</td>
<td>845</td>
<td>1,149</td>
<td>615</td>
<td>182</td>
</tr>
<tr>
<td>Former Smoker</td>
<td>7,583</td>
<td>13,734</td>
<td>9,389</td>
<td>6,105</td>
<td>2,872</td>
<td>657</td>
</tr>
</tbody>
</table>

HR = adjusted for age and sex
Current Smoker vs. Never Smoked: Entire Period HR=1.518 (1.225-1.881), p=0.0001
Former Smoker vs. Never Smoked: Entire Period HR=1.272 (1.173-1.379), p<0.0001

**INSIGHTS**

After elective primary total hip arthroplasty, current smoking status was associated with a rate of revision 1.52 times that of patients who have never smoked.
Revision Hip Arthroplasty

Between 2012 and 2018, AJRR has collected data on 43,940 revision hip arthroplasty procedures.

A substantial amount of work has been done since the last AJRR Annual Report to better identify and characterize the reasons for revision hip arthroplasty procedures. The data submitted to AJRR contains variability in coding with respect to primary reason for revision. Reason for revision was determined by the primary diagnosis code submitted for each revision. AJRR accepts up to 10 diagnosis codes which can be submitted as either ICD (International Classification of Diseases) -9 or -10 codes depending on the year of the procedure. To best produce analyses, much time was spent with surgeon leadership to identify the best approach for grouping and characterizing the numerous different codes.

The primary reasons for revision were examined and categorized as follows: periprosthetic osteolysis, fracture or fracture related sequelae (other than periprosthetic fracture), periprosthetic fracture, articular bearing surface wear, infection and inflammatory reaction, other mechanical complications, aseptic loosening, and instability related codes. If the primary code submitted did not fall into one of these categories, the subsequent reported codes were examined for a match. If none of the submitted codes matched a defined category, the primary reason for revision was placed in an “other” category. This category was then examined and all procedures with a non-relevant diagnosis were removed. In total, 9.4% (3,914) of revisions were removed from analyses due to irrelevant codes such as comorbidities, arthritis, or codes related to anatomic areas other than the hip. To account for an abundance of fracture codes not classified as periprosthetic fracture, this year a new category of “fracture or fracture-related sequelae” was created. Examples include “displaced intertrochanteric fracture” or “displaced subtrochanteric fracture of left femur, initial encounter for closed fracture” where it could not be definitively determined that the fracture was periprosthetic in nature. Pathological fractures were excluded from this group.

Using this methodology, the most common reason for hip revision surgery was instability at 19.1% (Figure 2.28). An early revision is considered one that occurred <3 months after the primary procedure. There were 6,978 early “linked” revision procedures in AJRR (Table 2.3). A “linked” revision is one in which the patient had the primary and revision surgery both done in a facility that submitted data to AJRR. In a study quantifying the level of migration of primary arthroplasty patients ≥65 years of age, Etkin et al noted only 0.62% of Medicare patients moved out of state and to a different county one year after the primary procedure. Migration to a different state or county increased to >10% at 5 years and 18% at 10 years. As a result, AJRR might be more likely to capture an early revision as those are most likely to return to the same AJRR hospital as the primary.21 Among revisions, only 3,923 had a primary diagnosis that was relevant using the methodology above. For all early revisions, the primary reason was infection and inflammatory diagnoses (23.0%) (Figure 2.29).

Figure 2.28 Primary Diagnosis Associated with All Hip Revisions, 2012-2018 (N=37,638)
The prevalence of early hip revisions after the age of 69 significantly increased with each increasing decade of life (p<0.0001) (Figure 2.30). Patients ≥90 years of age had the highest prevalence of early revision at 1.90%. For these patients the primary reason for revision was in the “other” category at 58.0%, second highest was instability/dislocation and fourth, periprosthetic fracture at <10%.

The prevalence of early hip revisions after the age of 69 significantly increased with each increasing decade of life. **Insights**

### Table 2.3 Time Interval Between Primary Hip Arthroplasty Procedures and Revision for “Linked” Patients, 2012-2018 (N=12,586)*

<table>
<thead>
<tr>
<th>Time from Primary to Revision</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3 Months</td>
<td>6,978 (55.4%)</td>
</tr>
<tr>
<td>3-5 Months</td>
<td>1,590 (12.6%)</td>
</tr>
<tr>
<td>6-12 Months</td>
<td>1,545 (12.3%)</td>
</tr>
<tr>
<td>&gt;1 Year</td>
<td>2,473 (19.6%)</td>
</tr>
</tbody>
</table>

*A linked patient has both a primary and revision procedure in AJRR

### Figure 2.29 ICD Diagnosis Codes for All Early “Linked” Hip Revisions, 2012-2018 (N=3,923)*

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Percent of All Early Hip Revisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection &amp; Inflammatory (n=903)</td>
<td>23.0%</td>
</tr>
<tr>
<td>Instability (n=774)</td>
<td>19.7%</td>
</tr>
<tr>
<td>Fracture or Fracture Related Sequelae (n=651)</td>
<td>16.6%</td>
</tr>
<tr>
<td>Other (n=620)</td>
<td>15.8%</td>
</tr>
<tr>
<td>Periprosthetic Fracture (n=609)</td>
<td>15.5%</td>
</tr>
<tr>
<td>Aseptic Loosening (n=207)</td>
<td>5.3%</td>
</tr>
<tr>
<td>Other Mechanical Complications (n=151)</td>
<td>3.9%</td>
</tr>
<tr>
<td>Articular Bearing Surface Wear (n=6)</td>
<td>0.2%</td>
</tr>
<tr>
<td>Periprosthetic Osteolysis (n=2)</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

*Early revisions are considered <3 months from date of primary surgery.

### Figure 2.30 Prevalence of Early Revision Following Primary Hip Arthroplasty by Age Group, 2012-2018 (N=6,978)*

*Unlinked revisions
When comparing the percentage of all hip arthroplasty revisions with a primary diagnosis of infection, the percentage varies from 6.9-11.9% over the years 2012-2018 (Figure 2.31). Similarly, for hip revisions due to instability/dislocation, the value appears to be increasing before dropping off in 2017 and then even more so in 2018 (Figure 2.32). As AJRR collects historical data, these numbers could change with further data collection.

**Figure 2.31** Revisions Due to Infection as a Percentage of All Hip Revisions by Year, 2012-2018 (N=4,217)*

**Figure 2.32** Revisions Due to Dislocation/Instability as a Percentage of All Hip Revisions by Year, 2012-2018 (N=6,413)*

*Unlinked revisions

“As a for-profit surgical center, we face a common industry misconception that the emphasis on patient care may not be our most prioritized focus. Not only did joining AJRR and becoming the first Joint Commission Advanced Total Hip and Total Knee Certified ASC in California help combat this, it also helped standardize our practices, streamline our processes, and got the entire staff working on the same team toward the same goal.”

Jessie Scott
Administrator
Presidio Surgery Center
AJRR saw a statistically significant increase in dual mobility usage for revision hip arthroplasty procedures when comparing 2012 to 2018 with 16.3% of articulations classified as dual mobility in 2018 (p<0.0001) (Figure 2.33). Not surprisingly, at the same time there has been a significant increase in overall dual mobility usage for revisions to treat dislocation/instability (p<0.0001) (Figure 2.34).

**Figure 2.33** Dual Mobility Usage and Femoral Head Sizes Implanted for Hip Revisions by Year, 2012-2018 (N=27,742)*

*Constrained implants excluded.

**Figure 2.34** Usage of Dual Mobility Implants for Hip Revisions Secondary to Dislocation/Instability, 2012-2018 (N=4,980)*

*Unlinked procedures
Revision burden is calculated by dividing the number of revision arthroplasties performed in one year by the total number of arthroplasties (revisions plus primaries) during the same year. Although crude, and influenced by numerous factors, revision burden can be used across registries as a simple unit of measure for comparison and quality improvement measures. In 2018, AJRR’s sample population had a revision burden for all total hip arthroplasty procedures of 4.7%, which continues to decline since 2013 (Figure 2.35). McGrory et al compared revision burden among international hip and knee joint registries and noted an overall decrease in hip revision burden from 2011-2014. Similarly, the Australian Orthopaedic Association National Joint Replacement Registry noted that while hip replacements had increased by 1.1% in 2017, the revision burden had remained stable at 8.9% (compared to 2016), an all-time low for the registry.

Figure 2.35 Hip Arthroplasty Revision Burden by Year, 2012-2018 (N=44,951)*

Although hip arthroplasty revision burden appears to be declining when calculated using AJRR data, numerous factors may be at play. As the Registry grows and new institutions submit data, a disproportionately large number of primary procedures may be added to the database, or the distribution of institutions performing primary versus revision surgery may change. Finally, even with the growth of AJRR, revisions performed outside the AJRR capture area would falsely decrease revision burden. Still, it is possible that at least some of the decrease is due to improvements in techniques and implants (decreasing use of metal-on-metal implants, increasing use of ultra-high-molecular-weight polyethylene (UHMWPE), etc.).

*Revision burden is calculated by dividing the number of revision arthroplasties performed in one year by the total number of arthroplasties (revisions plus primaries) during the same year.
Patient-Reported Outcome Measures (PROMs)

Patient-reported outcome measures (PROMs) have received increased attention within both registries and the wider practice of orthopaedic surgery. In the U.S., value-based payment models made capture of PROMs a prerequisite for various public and private alternative payment models. Internationally, in 2014 the International Society of Arthroplasty Registries (ISAR) steering committee established a working group in this area to advise on best practices.\(^\text{14}\)

Quick Facts:

- Collection of PROMs was initiated in the California Joint Replacement Registry (CJRR) in early 2011 and following incorporation of CJRR within AJRR began for the larger U.S. population in April 2016.

- To help assist AJRR institutions with PROM data collection, AJRR offers a PROM platform within RegistryInsights\(^\text{a}\) at no additional cost that allows for PROM storage and capture (both preoperatively and postoperatively).

- AJRR collects PROMs at any time but recommends at a minimum a preoperative (<90 days before the procedure) and a 1-year postoperative PROM.

- As of 2019, AJRR recommends and supports (on their PROM platform) the collection of HOOS JR., KOOS JR., PROMIS-10, and VR-12. Other PROMs are collected but not used for analyses.

- As of December 31, 2018, 61 sites out of 821 (7.4%) have submitted PROMs compared to 6.3% as listed in the 2018 Annual Report. As of June 30, 2019, this number more than doubled to 155.

- The completion rate for “linked” outcomes (those where both a preoperative and 1-year postoperative PROM is available on the same procedure) varies between 19.9-27.4%.

“Patient-reported outcomes are like the holy grail in orthopaedics. Nothing measures success of procedures like meeting the expectations of the patient in terms of healing, a return of functionality, and life improvement. PROs can tell us much more about true patient experience and satisfaction than we can get from more traditional clinical data.”

Andrew N. Pollak, MD
Senior Vice President for Clinical Transformation and Chief of Orthopaedics
University of Maryland Medical System
Table 2.4 Patient-Reported Outcome Measure (PROM) Preoperative and 1-Year Postoperative Mean Scores After Primary Hip Arthroplasty, 2012-2018

<table>
<thead>
<tr>
<th>Patient-Reported Outcome Measure (PROM)</th>
<th>PROM Component</th>
<th>Pre- or Postoperative</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOOS, JR. (Hip disability and Osteoarthritis Outcome Score)</td>
<td>Score</td>
<td>Preoperative</td>
<td>16,711</td>
<td>46.5</td>
<td>16.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postoperative</td>
<td>5,121</td>
<td>84.7</td>
<td>16.3</td>
</tr>
<tr>
<td>PROMIS-10 (Patient-Reported Outcomes Measurement Information System 10)</td>
<td>Mental T</td>
<td>Preoperative</td>
<td>9,901</td>
<td>49.3</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postoperative</td>
<td>3,249</td>
<td>52.9</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>Physical T</td>
<td>Preoperative</td>
<td>9,901</td>
<td>39.6</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postoperative</td>
<td>3,249</td>
<td>48.8</td>
<td>9.0</td>
</tr>
<tr>
<td>VR-12 (The Veterans RAND 12 Item Health Survey)</td>
<td>Mental Health Component</td>
<td>Preoperative</td>
<td>11,158</td>
<td>51.9</td>
<td>13.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postoperative</td>
<td>4,417</td>
<td>56.3</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>Physical Health Component</td>
<td>Preoperative</td>
<td>11,158</td>
<td>28.3</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postoperative</td>
<td>4,417</td>
<td>44.0</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*Meaningful improvement was calculated by minimal clinical important difference (MCID). MCID was determined to be a positive change score of half the pooled standard deviation. For calculation of MCID both a pre- and postoperative score is required. Preoperative PROMs are submitted less than 90 days before the procedure. Postoperative PROMs for this analysis are collected 1-year postoperatively. MCID was adjusted by age, sex, and race. Not all PROMs collected had acceptable data (age, sex, and race) to provide adjustment and were excluded.

Based on the HOOS, JR. score, 92.7% of patients achieved a meaningful improvement after elective primary total hip arthroplasty.
Knee Arthroplasty

Knee Overview

Between 2012 and 2018, AJRR has collected data on 922,853 knee arthroplasty procedures. The majority of knee surgeons submitting data to AJRR are performing primary total knee arthroplasties. There were 2,162 unique surgeons who submitted at least one knee arthroplasty case to AJRR in 2018. Of this group, the mean per surgeon volume of total knee arthroplasties was 44.8 with a range of 1-768 and an interquartile range (25th-75th percentile) of 7-56 (Table 3.1). These volumes are similar to that reported by Wilson et al. Partial knee arthroplasties include medial unicompartmental, lateral unicompartmental, and patellofemoral arthroplasty. Only surgeons with at least one relevant knee procedure were included.

Table 3.1 Average Procedural Volume for Participating Surgeons, 2018 (N=3,481)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Total Surgeons</th>
<th>Total Procedures</th>
<th>Per Surgeon Mean</th>
<th>Per Surgeon Median</th>
<th>Interquartile Range (25th percentile - 75th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Knee Arthroplasty</td>
<td>3,113</td>
<td>139,582</td>
<td>44.8</td>
<td>23</td>
<td>7-56</td>
</tr>
<tr>
<td>Partial Knee Arthroplasty</td>
<td>939</td>
<td>4,603</td>
<td>4.9</td>
<td>2</td>
<td>1-4</td>
</tr>
<tr>
<td>Revision Knee Arthroplasty</td>
<td>1,959</td>
<td>10,507</td>
<td>5.4</td>
<td>3</td>
<td>1-6</td>
</tr>
</tbody>
</table>

The mean age for individuals undergoing total knee arthroplasty was 67.0 (SD 9.6) years (Table 3.2 and Figure 3.1). There was a statistical difference in the average age between patients undergoing total knee arthroplasty (67.0 years) and partial knee arthroplasty (64.2 years) (p<0.0001) as well as total knee and revision knee arthroplasty (p<0.0001).

Table 3.2 Mean Age of Knee Arthroplasty Procedures, 2012-2018 (N=895,327)

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Mean Age (years)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Knee Arthroplasty</td>
<td>67.0</td>
<td>9.6</td>
</tr>
<tr>
<td>Partial Knee Arthroplasty</td>
<td>64.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Revision Knee Arthroplasty</td>
<td>65.6</td>
<td>11.3</td>
</tr>
</tbody>
</table>
When examining mean length of stay as reported to AJRR, there has been a significant decrease of 0.9 days for total knee arthroplasties comparing 2012 (2.9 (95% CI, 2.9-3.0)) to 2018 (2.0 (95% CI, 1.9-2.0)). A significant decrease in mean length of stay for partial knee arthroplasties of 1.2 days was also seen (Figure 3.2). For this analysis, length of stay was calculated by subtracting admission date from the discharge date and adding one. Data to accurately calculate length of stay was provided on only 11.1% of all knee cases.

**Figure 3.1** Age Distribution of All Knee Arthroplasty Procedures, 2012-2018 (N=894,201)

![Age Distribution of All Knee Arthroplasty Procedures](image)

**Figure 3.2** Mean Length of Stay for Knee Arthroplasty Patients by Year, 2012-2018 (N=99,096)

![Mean Length of Stay for Knee Arthroplasty Patients by Year](image)

*Upper and lower confidence limits for total knee arthroplasty in 2014 were equal to 2.7.*
Primary Total Knee Arthroplasty

Between 2012 and 2018, AJRR has collected data on 828,999 primary total knee arthroplasty procedures.

More than half of patients at all age points receiving a total knee arthroplasty were female (Figure 3.3). The sex distribution of patients remains fairly consistent as age increases.

Similar to past years, more than half of all primary total knee arthroplasty procedures in 2018 utilized posterior stabilized implants and 43.8% used cruciate retaining designs. Use of ultracongruent components has increased between 2012 and 2018, while use of more constrained implants (including varus-valgus and rotating linked hinged components) has remained consistent at around 0.1% (Figure 3.4). Similarly, there has been some consistency in the use of mobile-bearing designs for primary total knee arthroplasties which varies from 7-9% during this time period (Figure 3.5).

Use of ultracongruent components continues to increase whereas there has been little change in the use of mobile-bearing designs.
After adjusting for age and sex in patients ≥65 years of age as reported to either AJRR or CMS, cruciate retaining designs showed better survival (HR=0.766, 95% CI, 0.699-0.839, p<0.0001) compared to posterior stabilized designs. However, this difference was small (<1%) and does not account for numerous potential confounders (Figure 3.6).

**Figure 3.6** Primary Total Knee Arthroplasty Implant Designs in Patients >65 Years of Age with Primary Osteoarthritis and an Endpoint of Revision, 2012-2018*

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0–15</th>
<th>16–30</th>
<th>31–45</th>
<th>46–60</th>
<th>61–75</th>
<th>76–90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruciate Retaining</td>
<td>22,306</td>
<td>22,272</td>
<td>18,838</td>
<td>12,628</td>
<td>5,599</td>
<td>1,532</td>
</tr>
<tr>
<td>Posterior Stabilized</td>
<td>30,561</td>
<td>37,624</td>
<td>30,768</td>
<td>20,683</td>
<td>10,671</td>
<td>2,582</td>
</tr>
</tbody>
</table>

*For survivorship methodology see Appendix F

HR: adjusted for age and sex
Cruciate Retaining vs. Posterior Stabilized: Entire Period HR=0.766 (95% CI, 0.699-0.839), p<0.0001
For primary total knee arthroplasty procedures in this data set, antioxidant polyethylene usage has substantially increased at the expense of non-antioxidant polyethylene inserts between 2012 and 2018 (Figure 3.7). Non-antioxidant polyethylene included both conventional polyethylene (UHMWPE) and highly cross-linked polyethylene without antioxidant treatment.

In 2018, 90.6% of total knee arthroplasty procedures submitted to AJRR underwent patellar resurfacing (Figure 3.8). While patellar resurfacing remains the predominant practice in the U.S., this is not necessarily the case in other international registries. In 2018, the Australian Orthopaedic Association National Joint Replacement Registry reported patellar resurfacing at the time of the primary total knee replacement had increased from a low of 41.5% in 2005 to 66.6% in 2017. The Swedish Knee Arthroplasty Register reported use of patellar resurfacing has been decreasing since the mid-1980s and in 2017 was performed in only 2.4% of total knee arthroplasty cases.

Patellar resurfacing continues to be performed in the vast majority of total knee arthroplasties and total knee arthroplasties with resurfaced patellae showed better survival than unresurfaced with revision for any reason as an endpoint.
After adjusting for age and sex in patients ≥65 years of age in either AJRR or CMS, resurfaced patellae showed better survival than unresurfaced (HR=1.437, 95% CI, 1.268-1.629, p<0.0001). However, there were far more procedures with resurfaced patellae and this finding does not account for numerous potential confounders (Figure 3.9).

**Figure 3.9** Survivorship for Total Knee Arthroplasty Patellar-Resurfacing of Patients >65 Years of Age with Primary Osteoarthritis and an Endpoint of Revision, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unresurfaced</td>
<td>4,260</td>
<td>5,059</td>
<td>3,632</td>
<td>3,080</td>
<td>1,396</td>
<td>313</td>
</tr>
<tr>
<td>Resurfaced</td>
<td>88,301</td>
<td>105,554</td>
<td>85,567</td>
<td>56,824</td>
<td>31,370</td>
<td>8,688</td>
</tr>
</tbody>
</table>

HR: adjusted for age and sex
Unresurfaced vs. Resurfaced Patellae: Entire Period HR=1.437 (1.268-1.629), p<0.0001
In the United States, the use of polymethylmethacrylate (bone cement) for the fixation of primary total knee arthroplasty components is typical. However, the use of cementless fixation has seen an increase since 2012 ($p<0.0001$) (Figure 3.10). Similarly, the Swedish Knee Arthroplasty Register reported in their 2018 Annual Report that cementless fixation had become slightly more common and was now used in 7% of the total knee arthroplasties. In the 2018 National Joint Registry, more than 80% of all primary total knee arthroplasties utilized all cemented fixation. The use of all cementless and hybrid total knee replacements (2.2% in 2017) has decreased proportionally to less than one-third of those figures reported for 2003.

**Figure 3.10** Utilization of Cemented versus Cementless Fixation for Primary Total Knee Arthroplasty by Year, 2012-2018 (N=657,187)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cemented Fixation</th>
<th>Cementless Fixation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>5.9%</td>
<td>94.1%</td>
</tr>
<tr>
<td>2013</td>
<td>6.3%</td>
<td>93.7%</td>
</tr>
<tr>
<td>2014</td>
<td>5.6%</td>
<td>94.4%</td>
</tr>
<tr>
<td>2015</td>
<td>5.1%</td>
<td>94.9%</td>
</tr>
<tr>
<td>2016</td>
<td>6.0%</td>
<td>94.0%</td>
</tr>
<tr>
<td>2017</td>
<td>5.7%</td>
<td>94.3%</td>
</tr>
<tr>
<td>2018</td>
<td>8.4%</td>
<td>91.6%</td>
</tr>
</tbody>
</table>

Cementless fixation is increasing in popularity and after adjusting for age and sex, no difference in survivorship was seen between cemented and cementless fixation in primary total knee arthroplasties on patients ≥65 years of age using the AJRR and CMS databases.
After adjusting for age and sex, no difference in survivorship was seen between cemented and cementless fixation in primary total knee arthroplasties on patients ≥65 years of age using the AJRR and CMS databases (HR=1.302, 95% CI, 0.829-2.045, p=0.2512) (Figure 3.11). In just AJRR for patients <65 years of age, similar findings were noted for all patients as well as when evaluating males and females separately (Figures 3.12-3.14).

Figure 3.11 Survivorship of Cemented versus Cementless Fixation for a Primary Total Knee Arthroplasty for Patients >65 Years of Age Diagnosed with Primary Osteoarthritis and an Endpoint of Revision, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cemented</td>
<td>56,298</td>
<td>72,998</td>
<td>58,907</td>
<td>38,443</td>
<td>18,249</td>
<td>4,454</td>
</tr>
<tr>
<td>Cementless</td>
<td>311</td>
<td>219</td>
<td>198</td>
<td>310</td>
<td>212</td>
<td>28</td>
</tr>
</tbody>
</table>

HR: adjusted for age and sex
Cemented vs Cementless: Entire Period HR=1.302 (0.829-2.045), p=0.2512
Figure 3.12 Survivorship of Cemented versus Cementless Fixation for a Primary Total Knee Arthroplasty for Patients <65 Years of Age Diagnosed with Primary Osteoarthritis and an Endpoint of Revision as Submitted Only to AJRR, 2012-2018*

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cemented</td>
<td>34,625</td>
<td>45,716</td>
<td>39,415</td>
<td>26,792</td>
<td>12,227</td>
<td>2,472</td>
</tr>
<tr>
<td>Cementless</td>
<td>395</td>
<td>366</td>
<td>218</td>
<td>411</td>
<td>317</td>
<td>61</td>
</tr>
</tbody>
</table>

HR: adjusted for age and sex
Cemented vs. Cementless: Entire Period HR=1.102 (0.759-1.600), p=0.6099
**Figure 3.13** Survivorship of Cemented versus Cementless Fixation for a Primary Total Knee Arthroplasty for Females <65 Years of Age Diagnosed with Primary Osteoarthritis and an Endpoint of Revision as Submitted Only to AJRR, 2012-2018*

For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cemented</td>
<td>20,778</td>
<td>28,044</td>
<td>23,466</td>
<td>15,985</td>
<td>7,301</td>
<td>1,509</td>
</tr>
<tr>
<td>Cementless</td>
<td>209</td>
<td>188</td>
<td>116</td>
<td>180</td>
<td>124</td>
<td>25</td>
</tr>
</tbody>
</table>

*HR: adjusted for age
Cemented vs. Cementless: Entire Period HR=1.441 (0.867-2.394), p=0.1584
Figure 3.14 Survivorship of Cemented versus Cementless Fixation for a Primary Total Knee Arthroplasty for Males <65 Years of Age Diagnosed with Primary Osteoarthritis and an Endpoint of Revision as Submitted Only to AJRR, 2012–2018*

![Survivorship curve](image)

*For survivorship methodology see Appendix F

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0–15</th>
<th>16–30</th>
<th>31–45</th>
<th>46–60</th>
<th>61–75</th>
<th>76–90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cemented</td>
<td>13,840</td>
<td>17,649</td>
<td>15,934</td>
<td>10,801</td>
<td>4,926</td>
<td>963</td>
</tr>
<tr>
<td>Cementless</td>
<td>186</td>
<td>178</td>
<td>101</td>
<td>231</td>
<td>193</td>
<td>36</td>
</tr>
</tbody>
</table>

HR: adjusted for age
Cemented vs. Cementless: Entire Period HR=0.868 (0.502-1.499), p=0.6112
The association between patient comorbidities and survivorship will be an important area of investigation for AJRR. In initial analysis, smoking was examined. There appears to be an association between the presence of an administrative code for current or former smoking and decreased survivorship of a total knee arthroplasty in patients ≥65 years of age as reported to either AJRR or CMS. After adjusting for age and sex, current smoking status was associated with a rate of revision 1.48 times that of patients who have never smoked (HR=1.476, 95% CI, 1.209-1.803, p=0.0001) (Figure 3.15). It is important to emphasize that in an observational database like the AJRR, this finding remains an association and does not prove causation; the presence of potential confounders is likely. The inherent limitations to the use of administrative codes is also a limitation.

**Figure 3.15** Smoking Status and Survivorship for Primary Total Knee Arthroplasty for Patients >65 Years of Age with Primary Osteoarthritis and an Endpoint of Revision, 2012-2018*

<table>
<thead>
<tr>
<th>Smoking Status</th>
<th>Number at Risk (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never Smoked</td>
<td>101,025</td>
</tr>
<tr>
<td></td>
<td>111,417</td>
</tr>
<tr>
<td></td>
<td>89,320</td>
</tr>
<tr>
<td></td>
<td>61,820</td>
</tr>
<tr>
<td></td>
<td>33,539</td>
</tr>
<tr>
<td></td>
<td>8,307</td>
</tr>
<tr>
<td>Current Smoker</td>
<td>249</td>
</tr>
<tr>
<td></td>
<td>489</td>
</tr>
<tr>
<td></td>
<td>1,155</td>
</tr>
<tr>
<td></td>
<td>1,592</td>
</tr>
<tr>
<td></td>
<td>891</td>
</tr>
<tr>
<td></td>
<td>211</td>
</tr>
<tr>
<td>Former Smoker</td>
<td>11,431</td>
</tr>
<tr>
<td></td>
<td>23,492</td>
</tr>
<tr>
<td></td>
<td>16,830</td>
</tr>
<tr>
<td></td>
<td>11,077</td>
</tr>
<tr>
<td></td>
<td>5,461</td>
</tr>
<tr>
<td></td>
<td>1,107</td>
</tr>
</tbody>
</table>

HR: adjusted for age and sex
Current Smoker vs. Never Smoked: Entire Period HR=1.476 (1.209-1.803), p=0.0001
Former Smoker vs. Never Smoked: Entire Period HR=1.301 (1.213-1.395), p<0.0001

*For survivorship methodology see Appendix F
Partial Knee Arthroplasty

Between 2012 and 2018, AJRR has collected data on 37,847 partial knee arthroplasty procedures.

Medial or lateral unicompartmental knee arthroplasty (UKA) use has decreased in prevalence since 2012 and accounted for just 2.2% of all primary knee arthroplasties reported to AJRR for 2018 (Figure 3.16). Since there was a slight increase from the 1.9% usage seen in 2017, and AJRR collects historical data not submitted in real time, further changes in usage prevalence may be expected. Internationally, the Swedish Knee Arthroplasty Register noted in 2018 that the use of UKA accounted for almost 8% of their primary knee arthroplasty cases (a small increase from the previous year). Similarly, in 2018, the Australian Orthopaedic Association National Joint Replacement Registry reported a small increase in the last three years, attributing much of the increase to the use of one device utilized in association with robotic surgery.

The use of patellofemoral arthroplasty (PFA) in the AJRR remains a small percentage of single compartment arthroplasty and has been ≤0.2% since 2016 (Figure 3.17). These low numbers are consistent with international registries, where the New Zealand Joint Registry reported from 1999-2017 a total of 102,289 primary knee arthroplasties of which only 531 (<0.05%) represented patellofemoral prostheses. The National Joint Registry of England and Wales and the Swedish Knee Arthroplasty Register reported PFA in 2017 at 1.0% and 0.3% respectively.

Only 2.9% of all surgeons who submitted primary knee arthroplasty procedures to AJRR performed PFAs and only 15.9% performed medial and/or lateral UKAs. Moreover, there has been a significant decrease (p<0.0001) in the percentage of surgeons performing UKAs since 2015 (Table 3.3).

<table>
<thead>
<tr>
<th>Table 3.3</th>
<th>Surgeons Performing Patellofemoral and Unicompartmental Knee Arthroplasty, 2012-2018 (N=21,581)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeries Performing Type of Knee Arthroplasty</td>
<td>2012 n(%)</td>
</tr>
<tr>
<td>Medial and/or Lateral Unicompartmental Knee Arthroplasty</td>
<td>181 (20.3%)</td>
</tr>
<tr>
<td>Patellofemoral Arthroplasty</td>
<td>38 (4.3%)</td>
</tr>
<tr>
<td>Number of Surgeries Performing a Primary Knee Arthroplasty Procedure</td>
<td>890</td>
</tr>
</tbody>
</table>
In the AJRR or CMS database, total knee arthroplasty procedures demonstrated better survivorship than unicondylar knee arthroplasty constructs in patients \( \geq 65 \) years of age, though this result did not quite reach statistical significance (Figure 3.18). This finding is similar to other registries. In 2019, the National Joint Registry reported the number of revisions per 1,000 prosthesis-years for all causes to be 3.89 for cemented and 4.69 for cementless total knee arthroplasty, while that of unicondylar arthroplasty was 12.20 and patellofemoral arthroplasty was 20.45.\(^{18}\)

**Figure 3.18** Total Knee versus Uni-Condylar Knee Constructs for Femoral Components in Patients 65 Years of Age with Primary Osteoarthritis Age and Sex Adjusted, 2012-2018*

<table>
<thead>
<tr>
<th>Number at Risk (Months)</th>
<th>0-15</th>
<th>16-30</th>
<th>31-45</th>
<th>46-60</th>
<th>61-75</th>
<th>76-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>TKA</td>
<td>92,213</td>
<td>109,870</td>
<td>88,379</td>
<td>59,769</td>
<td>33,407</td>
<td>9,759</td>
</tr>
<tr>
<td>UNI</td>
<td>568</td>
<td>1,361</td>
<td>3,138</td>
<td>2,760</td>
<td>1,633</td>
<td>550</td>
</tr>
</tbody>
</table>

*Includes both medial and lateral UNIs. For survivorship methodology see Appendix F

*HR: adjusted for age and sex
Unicondylar vs. Total Knee Construct: Entire Period HR=1.15 (0.982-1.346), \( p=0.0832 \)
Revision Knee Arthroplasty

Between 2012 and 2018, AJRR has collected data on 58,409 revision knee arthroplasty procedures. As discussed in the hip arthroplasty section, a substantial amount of work has been done since the last AJRR Annual Report to better identify and characterize the reasons for revision knee arthroplasty procedures. The data submitted to AJRR contains variability in coding with respect to primary reason for revision. Substantial efforts involving surgeon leadership were undertaken to identify best practices for this critical coding step. First, reason for revision was determined by the primary diagnosis code submitted for each revision. AJRR accepts up to 10 diagnosis codes which can be submitted as either ICD (International Classification of Diseases) -9 or -10 codes depending on the year of the procedure. To best produce analyses, much time was spent with surgeon leadership to identify the best approach for grouping and characterizing the numerous different codes.

The primary reason for revision was then examined and categorized as follows: fracture or fracture related sequelae, articular bearing surface wear, instability related codes, infection and inflammatory reaction, mechanical loosening, and other mechanical complications. If the primary code submitted did not fall into one of these categories, the subsequent reported codes were examined for a match. If none of the submitted codes matched a defined category, the primary reason for revision was placed in an “other” category. This category was then examined and all procedures with a non-relevant diagnosis were removed. In total, 10.3% (5,676) of revisions were removed from analyses due to irrelevant codes such as comorbidities, arthritis, or codes related to anatomic areas other than the knee. To account for an abundance of fracture codes, this year a new category of “fracture or fracture related sequelae” was created. Examples include: “Other fracture of left patella, initial encounter for closed fracture” or “Unspecified fracture of unspecified patella, initial encounter for closed fracture.” Periprosthetic fractures were included in this group but only accounted for 15 revisions. Pathological fractures were excluded.

Using this methodology, the most common reason for knee revision surgery was mechanical loosening at 25.0% (Figure 3.19). An early revision is considered one that occurred <3 months after the primary procedure. There were 3,539 early “linked” revision procedures in AJRR (Table 3.4). A “linked” revision is one in which the patient had the primary and revision surgery both done in a facility that submitted data to AJRR. In a study quantifying the level of migration of primary arthroplasty patients ≥65 years of age, Etkin et al noted only 0.62% of Medicare patients moved out of state and to a different county one year after the primary procedure. Migration to a different state or county increased to >10% at 5 years and 18% at 10 years. As a result, AJRR might be more likely to capture an early revision, as those are most likely to return to the same AJRR hospital as the primary.21 Among revisions, only 2,899 had a primary diagnosis that was relevant using the methodology above. For all early revisions, the primary reason was infection and inflammatory diagnoses (63.2%) (Figure 3.20).

**Figure 3.19 Primary Diagnosis for All Knee Revisions, 2012-2018 (N=49,491)**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Percent of All Knee Revisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Loosening (n=12,359)</td>
<td>25.0%</td>
</tr>
<tr>
<td>Other Mechanical Complications (n=11,127)</td>
<td>22.5%</td>
</tr>
<tr>
<td>Infection &amp; Inflammatory Reaction (n=10,155)</td>
<td>20.5%</td>
</tr>
<tr>
<td>Other (n=7,053)</td>
<td>14.2%</td>
</tr>
<tr>
<td>Instability Related Codes (n=6,209)</td>
<td>12.6%</td>
</tr>
<tr>
<td>Articular Bearing Surface Wear (n=1,452)</td>
<td>2.9%</td>
</tr>
<tr>
<td>Fracture or Fracture Related Sequelae (n=1,136)</td>
<td>2.3%</td>
</tr>
</tbody>
</table>
As reported to AJRR, the percentage of primary total knee arthroplasty procedures with an early revision (<3 months from primary procedure) ranged from 0.38% to 0.69% and was most common in the <50 age group (p<0.0001) (Figure 3.21). Within the youngest age group, the primary reason for early revision was infection and inflammatory reaction (63.2%).

Table 3.4 Time Interval Between Primary Knee Arthroplasty Procedures and Revision for “Linked” Patients, 2012-2018 (N=14,803)*

<table>
<thead>
<tr>
<th>Time from Primary to Revision</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3 Months</td>
<td>3,539 (23.9%)</td>
</tr>
<tr>
<td>3-5 Months</td>
<td>1,611 (10.9%)</td>
</tr>
<tr>
<td>6-12 Months</td>
<td>2,986 (20.2%)</td>
</tr>
<tr>
<td>&gt;1 Year</td>
<td>6,667 (45.0%)</td>
</tr>
</tbody>
</table>

*A linked patient has both a primary and revision procedure in AJRR

Figure 3.20 Primary Diagnosis for All Early “Linked” Knee Revisions, 2012-2018 (N=2,899)

Figure 3.21 Early Revisions as a Percentage of All Primary Total Knee Arthroplasty Procedures by Age Group, 2012-2018 (N=3,539)*

As reported to AJRR, the percentage of primary total knee arthroplasty procedures with an early revision (<3 months from primary procedure) ranged from 0.38% to 0.69% and was most common in the <50 age group (p<0.0001) (Figure 3.21). Within the youngest age group, the primary reason for early revision was infection and inflammatory reaction (63.2%).

Patients <50 years of age had the highest incidence of early revision following total knee arthroplasty.
When comparing the percentage of revisions for all total knee arthroplasties with a primary diagnosis of infection, there has been an increase from 13.1% (95% CI, 11.5-14.8) in 2012 to 22.0% (95% CI, 21.1-22.8) in 2018 and this has been increasing steadily each year (Figure 3.22).

**Figure 3.22** Percentage of Revision Total Knee Arthroplasty Procedures Performed for the Indication of Infection, 2012-2018 (N=8,707)*

Antioxidant polyethylene usage in revision knee arthroplasties has been significantly increasing since 2012 (p<0.001) (Figure 3.23). Those listed as non-antioxidant polyethylene include other highly cross-linked polyethylene and conventional polyethylene (UHMWPE). In contrast, there has been little change in the use of mobile-bearing designs in the revision setting which fluctuates from 17.0-19.1% (Figure 3.24).

**Figure 3.23** Percentage of Antioxidant Polyethylene Usage by Year in Revision Knee Arthroplasty, 2012-2018 (N=40,995)

**Figure 3.24** Mobile-Bearing Designs as a Percentage of All Revision Total Knee Arthroplasty Procedures, 2012-2018 (N=7,501)*

*Unlinked revisions

*Includes rotating hinge and constrained condylar knee implants
As discussed earlier in the hip arthroplasty section, although crude and influenced by numerous factors, revision burden can be used across registries as a simple unit of measure for comparison and quality improvement. In 2018, AJRR’s sample population had a revision burden for all total knee arthroplasty procedures of 7.5%, which has been relatively consistent since 2012 (Figure 3.25). Similarly, McGrory et al compared revision burden among international hip and knee joint registries and noted revision burdens for knee replacements had remained relatively stable between 2011 and 2014. In 2017, this was the case for the Australian Orthopaedic Association National Joint Replacement Registry who noted that while knee replacement had increased by 5.0%, the revision burden had remained stable at 7.4% (compared to 2016), an all-time low for the Registry.

Although knee arthroplasty revision burden appears to be relatively stable when calculated with AJRR data, numerous factors may be at play. As the Registry grows and new institutions submit data, a disproportionately large number of primary procedures may be added to the database, or the distribution of institutions performing primary versus revision surgery may change. Finally, even with the growth of AJRR, revisions performed outside the AJRR capture area would falsely decrease revision burden. Still, it is possible that at least some of the decrease is due to improvements in techniques and implants.

**Figure 3.25 Knee Revision Burden by Year, 2012-2018 (N=58,409)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Knee Arthroplasty Revision Burden</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>6.5%</td>
</tr>
<tr>
<td>2013</td>
<td>6.5%</td>
</tr>
<tr>
<td>2014</td>
<td>7.8%</td>
</tr>
<tr>
<td>2015</td>
<td>7.4%</td>
</tr>
<tr>
<td>2016</td>
<td>6.9%</td>
</tr>
<tr>
<td>2017</td>
<td>6.4%</td>
</tr>
<tr>
<td>2018</td>
<td>7.5%</td>
</tr>
</tbody>
</table>

*Revision burden is calculated by dividing the number of revision arthroplasties performed in one year by the total number of arthroplasties (revisions plus primaries) during the same year.

**INSIGHTS**

Revision burden for all total knee arthroplasty procedures was 7.5% in 2018, which has been relatively consistent since 2012.
Patient-Reported Outcome Measures (PROMs)

As noted in the hip arthroplasty section, patient-reported outcome measures (PROMs) have received increased attention within both registries and the wider practice of orthopaedic surgery. In the U.S., value-based payment models made capture of PROMs a prerequisite for various public and private alternative payment models. Internationally, in 2014 the ISAR steering committee established a working group in this area to advise on best practices.14

Quick Facts:

- Collection of PROMs was initiated in the California Joint Replacement Registry (CJRR) in early 2011 and following incorporation of CJRR within AJRR began for the larger U.S. population in April 2016.
- To help assist AJRR institutions with PROM data collection, AJRR offers a PROM platform within RegistryInsights® at no additional cost that allows for PROM storage and capture (both preoperatively and postoperatively).
- AJRR collects PROMs at any time but recommends at a minimum a preoperative (<90 days before the procedure) and a 1-year postoperative PROM.
- As of 2019, AJRR recommends and supports (on their PROM platform) the collection of HOOS JR., KOOS JR., PROMIS-10, and VR-12. Other PROMs are collected but not used for analyses.
- As of December 31, 2018, 61 sites out of 821 (7.4%) have submitted PROMs compared to 6.3% as listed in the 2018 Annual Report. As of June 30, 2019, this number more than doubled to 155.
- The completion rate for “linked” outcomes (those where both a preoperative and 1-year postoperative PROM is available on the same procedure) varies between 19.9-27.4%.

“Our participation with AJRR came by way of our affiliation with MARCQI, the Michigan Arthroplasty Registry Collaborative Quality Initiative. Participation with both projects allows our team benchmarking on both a statewide and a national level, supporting the mission of improving joint replacement science through comparison and collaboration.”

Kristie Dennett, RN, MSN, ONC
Program Manager, Spine & Orthopedics
Holland Hospital
Table 3.5 Patient-Reported Outcome Measure (PROM) Preoperative and 1-Year Postoperative Mean Scores After Primary Knee Arthroplasty

<table>
<thead>
<tr>
<th>Patient-Reported Outcome Measure (PROM)</th>
<th>PROM Component</th>
<th>Pre or Postoperative</th>
<th>N</th>
<th>MEAN</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOOS, JR. (Knee injury and Osteoarthritis Outcome Score, Junior)</td>
<td>Score</td>
<td>Preoperative</td>
<td>28,597</td>
<td>46.5</td>
<td>14.3</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
<td>10,046</td>
<td>76.8</td>
<td>16.7</td>
<td></td>
</tr>
<tr>
<td>PROMIS-10 (Patient-Reported Outcomes Measurement Information System 10)</td>
<td>Mental T</td>
<td>Preoperative</td>
<td>18,233</td>
<td>50.1</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
<td>6,813</td>
<td>52.7</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical T</td>
<td>Preoperative</td>
<td>18,233</td>
<td>40.5</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
<td>6,813</td>
<td>47.7</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>VR-12 (The Veterans RAND 12 Item Health Survey)</td>
<td>Mental Health Component</td>
<td>Preoperative</td>
<td>17,606</td>
<td>53.3</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
<td>7,211</td>
<td>56.6</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical Health Component</td>
<td>Preoperative</td>
<td>17,606</td>
<td>29.7</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
<td>7,211</td>
<td>42.4</td>
<td>12.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.6 Change Between Preoperative and 1-Year Postoperative Patient-Reported Outcome Measure (PROM) Scores After Primary Knee Arthroplasty

<table>
<thead>
<tr>
<th>Patient-Reported Outcome Measure</th>
<th>PROM Component</th>
<th>Patients with Preoperative Score</th>
<th>Patients with Linked Postoperative Score</th>
<th>Response Rate, Percentage of Patients Who Completed a Preoperative and 1-year Score</th>
<th>Patients with Meaningful Improvement*</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOOS, JR. (Knee injury and Osteoarthritis Outcome Score, Junior)</td>
<td>Score</td>
<td>28,262</td>
<td>6,539</td>
<td>23.1%</td>
<td>88.5%</td>
</tr>
<tr>
<td>PROMIS-10 (Patient-Reported Outcomes Measurement Information System 10)</td>
<td>Mental T</td>
<td>18,093</td>
<td>4,085</td>
<td>22.6%</td>
<td>35.6%</td>
</tr>
<tr>
<td></td>
<td>Physical T</td>
<td>18,093</td>
<td>4,085</td>
<td>22.6%</td>
<td>68.3%</td>
</tr>
<tr>
<td>VR-12 (The Veterans RAND 12 Item Health Survey)</td>
<td>Mental Health Component</td>
<td>16,712</td>
<td>4,782</td>
<td>28.6%</td>
<td>34.4%</td>
</tr>
<tr>
<td></td>
<td>Physical Health Component</td>
<td>16,712</td>
<td>4,782</td>
<td>28.6%</td>
<td>72.8%</td>
</tr>
</tbody>
</table>

*Meaningful improvement was calculated by minimal clinical important difference (MCID). MCID was determined to be a positive change score of half the pooled standard deviation. For calculation of MCID both a pre- and postoperative score is required. Preoperative PROMs are submitted less than 90 days before the procedure. Postoperative PROMs for this analysis are collected 1 year postoperatively. MCID was adjusted by age, sex, and race. Not all PROMs collected had acceptable data (age, sex, and race) to provide adjustment and were excluded.

Based on the KOOS, JR. score, 88.5% of patients achieved a meaningful improvement after total knee arthroplasty.
## Appendix A

Data Element Review

<table>
<thead>
<tr>
<th>Procedural</th>
<th>Post-Operative, Complications</th>
<th>Patient-Reported Outcome Measures (PROMs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient</strong></td>
<td>Patient risk factors (ICD-9/10)*</td>
<td>Hip dysfunction and Osteoarthritis Outcome Score for Joint Replacement (HOOS, JR.) *</td>
</tr>
<tr>
<td>• Name (Last, First)</td>
<td>• Chronic lung disease</td>
<td>Knee injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS, JR.) *</td>
</tr>
<tr>
<td>• Date of birth</td>
<td>• Congestive heart failure</td>
<td>Patient-Reported Outcomes Measurement Information System (PROMIS) 10-item Global Health *</td>
</tr>
<tr>
<td>• Social Security Number</td>
<td>• Coronary artery disease</td>
<td>The Veterans RAND 12 Item Health Survey (VR-12) *</td>
</tr>
<tr>
<td>• Diagnosis (ICD-9/10)</td>
<td>• Diabetes mellitus</td>
<td>Harris Hip Score</td>
</tr>
<tr>
<td>• Gender</td>
<td>• Dialysis</td>
<td>Hip disability and Osteoarthritis Outcome Score (HOOS)</td>
</tr>
<tr>
<td>• Ethnicity</td>
<td>• History of venous thrombosis and embolism</td>
<td>Knee injury and Osteoarthritis Outcome Score (KOOS)</td>
</tr>
<tr>
<td><strong>Site of Service</strong></td>
<td>• Hypertension</td>
<td>Medical Outcomes Study 36-Item Short Form Health Survey (SF-36)</td>
</tr>
<tr>
<td>• Name (TIN/NPI)</td>
<td>• Obesity</td>
<td>Oxford Hip and Knee Scores</td>
</tr>
<tr>
<td>• Address</td>
<td>• Peripheral artery disease</td>
<td>The Knee Society Knee Scoring System</td>
</tr>
<tr>
<td><strong>Surgeon</strong></td>
<td>• Previous cardiac condition (past myocardial infarction)</td>
<td>Western Ontario and McMaster Universities Arthritis Index (WOMAC)</td>
</tr>
<tr>
<td>• Name</td>
<td>• Smoking status</td>
<td>*PROMs recommended by AJRR and supported on the PROM platform</td>
</tr>
<tr>
<td>• National Provider Identifier (NPI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td>Post-operative complications</td>
<td></td>
</tr>
<tr>
<td>• Type (ICD-9/10 and CPT)</td>
<td>• Early revisions</td>
<td></td>
</tr>
<tr>
<td>• Date of surgery</td>
<td>• Hospital re-admission</td>
<td></td>
</tr>
<tr>
<td>• Laterality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Implants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Surgical Approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• American Society of Anesthesiologists (ASA) classification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Comorbidities listed of focus, all comorbidities are accepted
Appendix B
Audit of Registry Data

The AAOS Registry Program and AJRR are committed to providing data reports that are valid and accurate. To ensure the Registry Program achieves this objective, internal quality controls are in place, in addition to an external audit of data from the previous year. The audit process is completed annually, and this year AJRR contracted with Quality Insights to serve as the vendor for auditing a sample of 2018 data. Quality Insights has a history of collaboration with non-profit medical organizations, specifically focusing on validating registry and health record data, and has assisted with AJRR’s audit in previous years.

The intention of this audit was to select and review a sample of 2018 data. The Registry randomly selected N=16 (2%), actively submitting AJRR sites, both hospitals and ambulatory surgical centers (ASCs), from January 1 to December 31, 2018 to participate. One hospital adjudicated during the 2018 audit and was required to participate this year, creating a total of 17 sites for the 2019 audit. The participating sites represented urban and rural locations, in addition to small and large institution size.

There are two portions of the audit to evaluate Registry data: the first portion of the audit was a medical records review, structured to analyze 30 randomly selected hip and knee arthroplasty procedures performed in 2018. The second portion was a completeness audit to evaluate the overall case completeness of all hip and knee procedures performed in one randomly selected month of 2018. The audit process ensures data submitted to AJRR correctly represents the data in the facility medical records, and that the data submitted to AJRR for a randomly selected month in 2018 reflected all hip and knee arthroplasty procedures performed at that site. The audit was completed in late September 2019.

Two of the randomly selected sites for the 2019 audit were unable to participate and were issued an exclusion waiver due to personnel changes. Additionally, two randomly selected sites were issued an exclusion waiver due to transitions in electronic health record (EHR) systems and/or ability to process the request by the established timeline. Audit participation is required, and verbiage is included in all AJRR site contracts; these four sites will be required to participate in the 2020 Annual Audit. This resulted in 13 participating sites and a total of 390 records for the 2019 AAOS/AJRR Audit. One site was unable to meet the data submission deadline for inclusion in aggregate summary; as a result, 12 sites were audited and aggregated for this report.

This year, none of the 12 sites requested adjudication of their results. The final overall audit agreement rate was 95.4%, which was slightly higher than the 94.5% overall audit agreement rate for the 17 sites participating in 2018 and slightly lower than the 98.4% and 96.9% overall audit agreement rate for the 2017 and 2016 audits. Since inception of the AJRR Annual Audit, the overall audit agreement rate has consistently exceeded 90%, above the 85% “acceptable” threshold, indicating high reliability of the data within the AJRR.

The overall record completeness assessment rate was 93.0%, up from 75.0% last year. Nine of the 12 sites achieved match rates ≥81.8% for both record validity and completeness assessment. Two sites had match rates ≤85% for both record validity and completeness assessment. One site had a record validity match rate of 88.9% and completeness assessment match rate of 61.5%. One site scored in the <55% “unacceptable” category for both record validity and completeness assessment. The record volume and performance of this site had a negative effect on the overall aggregate results. Due to these anomalous results, ad hoc calculations excluding the site were performed. Challenges in completeness agreement include formatting issues with reports that participants submitted to Quality Insights, therefore creating mismatches. Mismatches were also linked to documentation of laterality and institution NPI. There were no anomalous observations to suggest any cherry picking or selection of only the best cases being submitted.

This audit reflects agreement between the information in the institution record and the information as reported to AJRR. The audit does not reflect whether data and resulting codes assigned in the hospital record were the most appropriate or accurate for the procedure performed. Efforts to address accuracy and appropriateness of the submitted data, especially at the point of data entry, will continue in collaboration with all participating sites.
The AAOS Authorized Vendor Program was created to minimize the data entry burden and enhance the data submission process. The following vendors have been approved for this program.

✅ Amkai Solutions
✅ Cedaron
✅ Cerner*
✅ Clarify Health Solutions
✅ CODE Technology
✅ Consensus Medical Systems, Inc.
✅ Direct Difference
✅ Duet Health
✅ Epic*
✅ FORCE Therapeutics
✅ Invivolink, Inc.
✅ Kermit
✅ MedTrak, Inc. (CareSense System)
✅ [m]pirik

✅ OM1
✅ Ortech, Inc.
✅ OrthoSensor, Inc.
✅ OutcomeMD
✅ Promapp
✅ Q-Center
✅ Ratchet Health
✅ Ready Surgery
✅ URS-Oberd, Inc.
✅ ValidCare
✅ VisionTree
✅ VitalHealth Software
✅ Vox Telehealth
✅ Wellbe, Inc.
✅ Wellpepper, Inc.

*Vendors who have data extract templates

For updates to the list and more information on the AAOS Authorized Vendor Program, please visit here.
Appendix D

AJRR Committees

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Palo Alto Medical Foundation

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Orthopaedic Specialty Institute

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Manhattan Beach, CA

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OrthoCarolina

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Plano Orthopaedics and Sports Medicine Center

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University of Virginia

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Rothman Institute at Jefferson

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Stanford University

Richard L. Illgen II, MD
University of Wisconsin

Timothy M. Mojonnier
River Forest, IL

Susan M. Odum, PhD
OrthoCarolina Research Institute

Scott M. Sporer, MD
Midwest Orthopaedics at Rush and Central DuPage Hospital

Diana Stilwell, MPH
Sharon, MA

Paul Voorhorst
DePuy Synthes

David G. Lewallen, MD – Ex-Officio
Mayo Clinic

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Plano Orthopaedics and Sports Medicine Center

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University of Michigan

Timothy M. Mojonnier
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OrthoCarolina Research Institute

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UTHealth

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OrthoCarolina

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University of Virginia

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University of California, San Francisco and San Francisco VA Health Care System

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First Settlement Orthopaedics

Bryan D. Springer, MD
OrthoCarolina

Diana Stilwell, MPH
Sharon, MA

David G. Lewallen, MD – Ex-Officio
Mayo Clinic

**AJRR Research Projects Subcommittee**

Richard L. Illgen II, MD – Chair
University of Wisconsin

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Rothman Institute at Jefferson

Alejandro Della Valle, MD
Hospital for Special Surgery

Hilal Maradit Kremers, MD
Mayo Clinic

James Slover, MD, MS
NYU Langone Orthopedic Hospital

Timothy Wright, PhD
Hospital for Special Surgery

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Sharon, MA

Timothy M. Mojonnier
River Forest, IL
Appendix E
Participating Institutions

**Alabama**
- Cullman Regional Medical Center
- Huntsville Hospital
- Jack Hughston Memorial Hospital
- South Baldwin Regional Medical Center
- St. Vincent’s Birmingham

**Arkansas**
- Arkansas Surgical Hospital
- CHI St. Vincent Infirmary
- Martin Knee & Sports Medicine Center
- Mercy Hospital Northwest Arkansas
- Mercy Orthopedic Hospital Fort Smith
- OrthoSurgeons
- University of Arkansas for Medical Sciences
- Central Peninsula Hospital
- National Park Medical Center
- White River Medical Center

**Arizona**
- Arizona Spine & Joint Hospital
- Banner - University Medical Center South
- Carondelet St. Joseph’s Hospital
- Flagstaff Medical Center
- Mountain Vista Medical Center
- Northwest Medical Center*
- OASIS Hospital
- Verde Valley Medical Center
- Banner - University Medical Center Tucson
- Chandler Regional Medical Center
- Gateway Surgery Center
- Mercy Gilbert Medical Center
- Oro Valley Hospital*
- Shane Martin, MD of Greater Phoenix Orthopedics
- St. Luke’s Medical Center
- Sonoran Orthopaedic Trauma Surgeons

**California**
- Adventist Health Bakersfield
- Adventist Health Hanford
- Adventist Health Lodi Memorial
- Adventist Health St. Helena
- Alta Bates Summit Medical Center | Alta Bates Campus
- Alta Bates Summit Medical Center | Summit Campus
- California Pacific Medical Center
- Cedars-Sinai Medical Center
- Clovis Community Medical Center
- Community Hospital of the Monterey Peninsula
- Community Memorial Hospital
- Dameron Hospital
- Doctors Medical Center of Modesto
- Eisenhower Medical Center
- El Camino Hospital, Los Gatos Campus
- Feather River Hospital
- Fresno Surgical Hospital
- Glendale Adventist Medical Center
- Hoag Orthopedic Institute
- Howard Memorial Hospital
- Huntington Hospital
- John Muir Health, Concord Medical Center
- John Muir Health, Walnut Creek Medical Center
- Keck Medicine of USC
- Long Beach Medical Center
- Memorial Medical Center
- Mercy General Hospital*
- Methodist Hospital of Sacramento
- Mills-Peninsula Medical Center
- Mission Hospital - Mission Viejo
- Monterey Peninsula Surgery Center
- NorthBay VacaValley Hospital
- Novato Community Hospital*
- Orange Coast Medical Center
- Palomar Medical Center Escondido
- Palomar Medical Center Poway
- Petaluma Valley Hospital
- PIH Health - Whittier
- Pomona Valley Hospital Medical Center
- Presidio Surgery Center*
- Providence Holy Cross Medical Center
- Providence Little Company of Mary Medical Center San Pedro
- Providence Little Company of Mary Medical Center Torrance
- Providence Saint John’s Health Center
- Providence Saint Joseph Medical Center
- Providence Santa Rosa Memorial Hospital
- Providence St. Jude Medical Center

Institutions that submitted data for this Annual Report are highlighted in blue.

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- Providence Tarzana Medical Center
- Queen of the Valley Medical Center
- Redwood Memorial Hospital
- Riverside Community Hospital
- Ronald Reagan UCLA Medical Center
- Saddleback Medical Center
- Saint Agnes Medical Center
- Salinas Valley Memorial Healthcare System
- San Antonio Regional Hospital
- Scripps Green Hospital
- Sharp Chula Vista Medical Center
- Sharp Coronado Hospital
- Sharp Grossmont Hospital
- Sharp Memorial Hospital
- Shasta Regional Medical Center
- Simi Valley Hospital
- Sonoma Valley Hospital
- Sonora Regional Medical Center
- St. Joseph Hospital Eureka
- St. Joseph’s Medical Center
- St. Mary Medical Center
- St. Bernardine Medical Center
- Stanford Health Care
- Sutter Medical Center, Sacramento Surgery Center
- Tahoe Forest Hospital
- Torrance Memorial Medical Center
- Tri-City Medical Center
- UCLA Medical Center, Santa Monica
- UCSF Medical Center
- Ukiah Valley Medical Center
- Washington Hospital Healthcare System
- White Memorial Medical Center
- Bakersfield Memorial Hospital
- Barton Memorial Hospital
- Campus Surgery Center
- Carlsbad Surgery Center
- Coast Surgery Center
- Corona Regional Medical Center
- Desert Regional Medical Center
- Dignity Health - St. Mary Medical Center
- Dominican Hospital
- Eden Medical Center
- Enloe Medical Center
- Fort Sutter Surgery Center
- Goleta Valley Cottage Hospital*
- Good Samaritan Hospital
- Henry Mayo Newhall Hospital
- Inland Valley Medical Center
- La Jolla Orthopedic Surgery Center
- Los Robles Regional Medical Center
- Mammoth Hospital
- Marian Regional Medical Center
- Memorial Hospital Los Banos
- Memorial Medical Center
- Mercy Hospital Downtown - Bakersfield
- Mercy Hospital of Folsom
- Mercy Medical Center Merced*
- Mercy Medical Center Redding
- Mercy San Juan Medical Center
- Mission Valley Heights Surgery Center
- North Bay Regional
- NorthBay Medical Center
- Northridge Hospital Medical Center
- North Tahoe Orthopedics
- Ojai Valley Community Hospital
- Otay Lakes Surgery Center
- Palmdale Regional Medical Center
- Poway Surgery Center
- Providence St. Joseph Hospital of Orange
- Rancho Springs Medical Center*
- Redlands Community Hospital
- Riverside University Health System*
- San Leandro Surgery Center
- Santa Barbara Cottage Hospital*
- Santa Rosa Surgery and Endoscopy Center
- Sequoia Hospital
- St. Helena Hospital*
- St. John’s Pleasant Valley Hospital
- St. John’s Regional Medical Center
- St. Jude Medical Center*
- Stockton Surgery Center
- Surgery Center of Long Beach
- Sutter Alhambra Surgery Center
- Sutter Amador Hospital
- Sutter Auburn Faith Hospital
- Sutter Auburn Surgery Center
- Sutter Davis Hospital Outpatient (Ambulatory) Surgery Center
- Sutter Elk Grove Surgery Center
- Sutter Fairfield Surgery Center
- Sutter Maternity & Surgery Center
- Sutter North Surgery and Endoscopy Center
- Sutter Roseville Medical Center Surgery Center
- Sutter Sierra Surgery Center
- Sutter Solano Medical Center
- Sutter Surgical Hospital North Valley
- Sutter Tracy Community Hospital
- Temecula Valley Hospital
- The Bahamas Surgery Center
- The Center for Orthopedic Surgery
- West Hills Hospital & Medical Center

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Institutions that submitted data for this *Annual Report* are highlighted in blue.

<table>
<thead>
<tr>
<th>State</th>
<th>Institutions</th>
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</thead>
<tbody>
<tr>
<td><strong>Colorado</strong></td>
<td>Animas Surgical Hospital Avista Adventist Hospital Boulder Community Health</td>
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<tr>
<td></td>
<td>Castle Rock Adventist Hospital Crown Point Surgery Center Denver Health</td>
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<td></td>
<td>Littleton Adventist Hospital Longmont United Hospital Medical Center of the</td>
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<td></td>
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<td></td>
<td>LLC Poudre Valley Hospital St. Anthony Hospital St. Anthony North Health Campus</td>
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<td></td>
<td>University of Colorado Hospital Colorado Joint Replacement North Suburban</td>
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<tr>
<td></td>
<td>Medical Center Panorama Orthopedics &amp; Spine Center Penrose-St. Francis Urgent</td>
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<tr>
<td></td>
<td>Care Presbyterian St. Luke’s Medical Center Rose Medical Center Sky Ridge</td>
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<tr>
<td></td>
<td>Medical Center Swedish Medical Center The Medical Center of Aurora</td>
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<td><strong>Delaware</strong></td>
<td>Bayhealth Hospital, Kent Campus Bayhealth Hospital, Sussex Campus Christiana</td>
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<tr>
<td></td>
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<td>George Washington University Hospital</td>
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<td><strong>Florida</strong></td>
<td>Baptist Hospital Bartow Regional Medical Center Cape Coral Hospital</td>
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<td>Cleveland Clinic Florida Cleveland Clinic Indian River Hospital Dr. P.</td>
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<td>Flagler Hospital Gulf Breeze Hospital Gulf Coast Medical Center</td>
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<td>South Florida Baptist Hospital</td>
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<td>St. Joseph's Hospital - North St. Joseph’s Hospital Tampa St. Joseph’s Hospital</td>
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<td>- South Tallahassee Memorial Healthcare Winter Haven Hospital</td>
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<td></td>
<td>AdventHealth Waterman AdventHealth Winter Park AdventHealth-Zephyrhills</td>
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<td>Hospital* Andrews Institute for Orthopaedics &amp; Sports Medicine Ascension St.</td>
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<td>Vincent’s Medical Center Clay County Hospital Ascension St. Vincent’s Medical</td>
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<td></td>
<td>Center Riverside Hospital Ascension St. Vincent’s Southside Hospital</td>
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<td></td>
<td>Aventura Hospital and Medical Center Blake Medical Center Brandon Regional</td>
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<td><strong>Connecticut</strong></td>
<td>Hartford Hospital Hospital of Central Connecticut</td>
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</table>

*Achieved The Joint Commission Advanced Certification for Total Hip and Total Knee Replacement*
Institutions that submitted data for this Annual Report are highlighted in blue.

Broward Health North*
Cleveland Clinic Florida - Weston
Cleveland Clinic Martin South Hospital
Cleveland Clinic Tradition Hospital
Coral Gables Hospital*
Doctors Hospital of Sarasota
Fawcett Memorial Hospital
Florida Joint & Spine Institute
Fort Walton Beach Medical Center
Gulf Coast Regional Medical Center
Holy Cross Hospital
Indian River Hospital*
JFK Medical Center
Jupiter Medical Center
Kendall Regional Medical Center
Lakewood Ranch Medical Center
Largo Medical Center
Manatee Memorial Hospital
Medical Center Clinic
Medical Center of Trinity
Memorial Hospital Jacksonville
Memorial Hospital of Tampa
North Florida Regional Medical Center
Oak Hill Hospital
Ocala Regional Medical Center
OrthoCare Florida
Orthopedic Center of Palm Beach County
Orthopedic Special Surgery of the Palm Beaches
Orthopaedic Surgery Center
Orthopaedic Surgery Center of Ocala
Osceola Regional Medical Center
Palms of Pasadena Hospital
Pensacola Orthopaedics & Sports Medicine
Physicians Regional Medical Center - Collier Boulevard
Physicians Regional Medical Center - Pine Ridge
Regional Medical Center Bayonet Point
South Bay Hospital
St. Lucie Medical Center
The Orthopaedic Institute
Toman Orthopedics and Sports Medicine
UF Health Shands Hospital
University Hospital & Medical Center
University of Florida Health
Wellington Regional Medical Center
West Florida Hospital
Weston Outpatient Surgical Center
Westside Regional Medical Center

Georgia
Atlanta Medical Center
Atlanta Medical Center South
Colquitt Regional Medical Center
Houston Medical Center
Memorial University Medical Center
Navicent Health
Optim Medical Center - Tattnall
Optim Surgery Center
Piedmont Columbus Regional Northside Campus
Redmond Regional Medical Center
Southeast Georgia Health System - Brunswick Campus
Southeast Georgia Health System - Camden Campus
WellStar Cobb Hospital
WellStar Douglas Hospital
WellStar Kennestone Hospital*
WellStar Paulding Hospital
WellStar Spalding Regional Hospital
WellStar West Georgia Medical Center
Cartersville Medical Center
Coliseum Medical Centers
Coliseum Northside Hospital

Eastside Medical Center
Emory University Orthopaedics & Spine Hospital
St. Mary's Good Samaritan Hospital
St. Mary's Hospital
St. Francis Health*
Summit Sports Medicine & Orthopedic Surgery

Hawaii
Adventist Health Castle
Pali Momi Medical Center
Straub Clinic and Hospital
The Queen's Medical Center*
Wilcox Memorial Hospital
Hawaii Pacific Health

Idaho
Cassia Regional Medical Center
Northwest Specialty Hospital
St. Alphonsus Medical Center Nampa Campus
St. Alphonsus Regional Medical Center
St. Luke's Boise Medical Center
St. Luke's Meridian Medical Center

Illinois
Adult & Pediatric Orthopedics
Blessing Health System
Centegra Hospital McHenry
Centegra Hospital Woodstock
Genesis Medical Center, Silvis
Gibson Area Hospital
Memorial Medical Center - Springfield
NorthShore University HealthSystem Evanston Hospital
NorthShore University HealthSystem Glenbrook Hospital
NorthShore University HealthSystem Highland Park Hospital

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AAOS American Joint Replacement Registry 2019 Annual Report
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NorthShore University HealthSystem
Skokie Hospital
Northwestern Medicine Central
DuPage Hospital
Northwestern Medicine Delnor
Hospital
Northwestern Memorial Hospital
Ortho Illinois
Orthopedic & Sports Medicine Clinic
Palos Community Hospital
Rockford Memorial Hospital
Rush University Medical Center
Valley Ambulatory Surgery Center
Weiss Memorial Hospital
Advocate BroMenn Medical Center
Advocate Christ Medical Center
Advocate Condell Medical Center
Advocate Eureka Hospital
Advocate Good Samaritan Hospital
Advocate Good Shepherd Hospital
Advocate Illinois Masonic Medical Center
Advocate Lutheran General Hospital
Advocate Sherman Hospital
Advocate South Suburban Hospital
Advocate Trinity Hospital
Bonutti Orthopedic Clinic
Center For Minimally Invasive Surgery
Decatur Orthopaedic Center
EvergreenHealth
Gold Coast Surgicenter
Gottlieb Memorial Hospital
HSHS St. Anthony’s Memorial Hospital*
HSHS St. John’s Hospital
Loyola University Medical Center
Memorial Hospital of Carbondale
Mercy Hospital & Medical Center
Mosaic Healthcare
Mount Sinai Hospital
Northwestern Medicine Kishwaukee Hospital*
Northwestern Medicine Lake Forest Hospital
OSF Heart of Mary Medical Center
OSF Holy Family Medical Center
OSF Sacred Heart Medical Center
OSF Saint Anthony Medical Center
OSF Saint Anthony’s Health Center
OSF Saint Elizabeth Medical Center
OSF Saint Francis Medical Center
OSF Saint James - John W. Albrecht Medical Center
OSF Saint Luke Medical Center
OSF Saint Paul Medical Center
OSF St. Joseph Medical Center
OSF St. Mary Medical Center
Raycraft & Jones Orthopaedics
Riverside Medical Center
SIH Herrin Hospital
South Shore Hospital
Swedish American Hospital
UnityPoint Health - Methodist
UnityPoint Health - Proctor
UnityPoint Health - Trinity Rock Island

Indiana
Allied Physicians Surgery Center
Franciscan Health Carmel
Franciscan Health Indianapolis
Franciscan Health Mooresville
IU Health Ball Memorial Hospital
Major Health Partners Medical Center
OrthoIndy Northwest
St. Mary Medical Center*
Columbus Regional Hospital
Hancock Regional Hospital
Indiana Hand to Shoulder Center
Indiana University Health Methodist Hospital
Indiana University Health West Hospital
Indiana University Health White Memorial Hospital
IU Health Arnett Hospital
IU Health Bedford Hospital
IU Health Beltway Surgery Centers
IU Health Blackford Hospital
IU Health Bloomington Hospital*
IU Health Eagle Highlands Surgery Center
IU Health Jay Hospital
IU Health Meridian South Surgery Center
IU Health Morgan
IU Health North Hospital
IU Health Paoli Hospital
IU Health Saxony Hospital
IU Health Saxony Surgery Center
IU Health Tipton Hospital
IU Health University Hospital
Main Hospital
Memorial Hospital and Health Care Center
Plymouth Medical Center
Porter Regional Hospital
Riley Hospital for Children at IU Health
Riverview Health Westfield Hospital
Schneck Medical Center
Senate Street Surgery Center
St. Joseph Regional Medical Center
The Orthopedic Hospital

Iowa
Allen Hospital
Buena Vista Regional Medical Center
CHI Health Mercy Council Bluffs*
Finley Hospital
Genesis Medical Center, Davenport
Great River Orthopaedic Specialists
Iowa Lutheran Hospital
Iowa Methodist Medical Center

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Iowa Specialty Hospital - Clarion
Lakes Regional Healthcare
Marengo Memorial Hospital
Mercy Medical Center - Cedar Rapids
Mercy Medical Center - Clinton
Mercy Medical Center - Des Moines
Mercy Medical Center - Dubuque
Mercy Medical Center - Sioux City
Mercy Medical Center - West Lakes
MercyOne North Iowa Medical Center
Methodist West Hospital
Mississippi Valley Surgery Center
Spencer Hospital
St. Luke’s Hospital
St. Luke’s Regional Medical Center
UnityPoint Health - Trinity Bettendorf
UnityPoint Health - Trinity Muscatine
UnityPoint Health - Trinity Regional Medical Center
UnityPoint Marshalltown
University of Iowa Hospitals & Clinics
Capital Orthopedics
CHI Health Mercy Cornning
Mercy Medical Center - Clinton
Mercy Medical Center Sioux City
MercyOne Des Moines Medical Center
MercyOne New Hampton Medical Center
MercyOne Primghar Medical Center
Orthopaedic Outpatient Surgery Center
Steindler Orthopedic Clinic
VA Central Iowa Health Care System

Stormont-Vail Health*
The University of Kansas Health System
Wesley Medical Center
AdventHealth Ottawa
Bob Wilson Memorial Hospital
LMH Health
Menorah Medical Center
St. Rose Ambulatory & Surgery Center
Wesley Woodlawn Hospital & ER

Kentucky
Jewish Hospital
Saint Joseph East
St. Elizabeth Hospital Edgewood
Bluegrass Orthopaedics
Hardin Memorial Hospital*
Methodist Hospital
Norton Audubon Hospital
Norton Brownsboro Hospital
Norton Hospital
Norton Women’s & Children’s Hospital
South Central Kentucky Orthopedics
TriStar Greenview Regional Hospital

Louisiana
Doctors Hospital at Deer Creek
Lafayette Surgical Specialty Hospital
Ochsner Baptist - A Campus of Ochsner Medical Center
Ochsner Medical Center
Ochsner Medical Center - Kenner
Ochsner Medical Center - West Bank Campus
Our Lady of Lourdes Regional Medical Center
Specialists Hospital Shreveport
Thibodeaux Regional Medical Center
Lafayette Bone & Joint Clinic
Lafayette General Medical Center

Red River Surgery Center
West Bank Surgery Center

Maine
Falmouth Orthopedic Center
Maine Medical Center
MaineGeneral Medical Center

Maryland
Anne Arundel Medical Center
Atlantic General Hospital
Holy Cross Germantown Hospital
Holy Cross Hospital
Howard County General Hospital
Johns Hopkins Bayview Medical Center*
MedStar Union Memorial Hospital
Meritus Medical Center
Peninsula Regional Medical Center*
Saint Agnes Healthcare
Suburban Hospital
Surgery Center of Easton
University of Maryland Baltimore Washington Medical Center
University of Maryland Harford Memorial Hospital
University of Maryland Medical Center
University of Maryland Medical Center Midtown Campus
University of Maryland Rehabilitation & Orthopaedic Institute
University of Maryland Shore Medical Center at Easton
University of Maryland St. Joseph Medical Center
University of Maryland Upper Chesapeake Health
Western Maryland Health System
Atlantic General Medical Center

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**Massachusetts**
- Berkshire Medical Center
- Beth Israel Deaconness Hospital - Plymouth
- Beth Israel Deaconness Medical Center
- Beverly Hospital
- Boston Medical Center
- Good Samaritan Medical Center
- Holy Family Hospital
- Lahey Hospital & Medical Center
- New England Baptist Hospital*
- Quincy Medical Center
- Saint Anne’s Hospital
- Signature Healthcare Brockton Hospital
- South Shore Hospital
- Sports Medicine North Orthopedic Surgery
- Boston Out-Patient Surgical Suites, LLC
- Charlton Memorial Hospital
- Longview Orthopaedic Center, LLC
- Massachusetts General Hospital
- Mercy Medical Center
- Mercy Medical Center of Sisters of Providence
- St. Luke’s Hospital

**Michigan**
- Ascension Borgess Medical Center
- Bronson Battle Creek Hospital
- Bronson LakeView Hospital
- Bronson Methodist Hospital
- Bronson South Haven Hospital
- Henry Ford Hospital
- Henry Ford Macomb Hospital
- Henry Ford West Bloomfield Hospital
- Henry Ford Wyandotte Hospital
- Holland Hospital
- Hurley Medical Center
- McLaren Flint
- McLaren Greater Lansing
- Mercy Health Hackley
- Mercy Health Muskegon
- Mercy Health Saint Mary’s
- Michigan Surgical Hospital
- MidMichigan Medical Center - Midland
- Munson Healthcare Cadillac Hospital
- Munson Medical Center
- Providence-Providence Park Hospital-Southfield
- Sparrow Health System
- Spectrum Health Hospitals Blodgett Hospital
- Spectrum Health Lakeland
- Spectrum Health Ludington Hospital
- St. Joseph Mercy Ann Arbor*
- St. Joseph Mercy Chelsea
- St. Joseph Mercy Oakland Hospital
- St. Mary Mercy Livonia Hospital
- St. Joseph Mercy Livingston Hospital
- University of Michigan Health System
- UP Health System - Marquette
- William Beaumont Hospital
- Ascension Genesys Hospital
- Ascension Macomb-Oakland Hospital, Madison Heights Campus
- Ascension Macomb-Oakland Hospital, Warren Campus
- Ascension Providence Hospital, Novi Campus
- Ascension Providence Hospital, Southfield
- Memorial Healthcare
- Mercy Health Lakeshore
- Mercy Health Mercy Campus
- Mercy Health Southwest
- Muskegon Surgery Center
- OSF St. Francis Hospital & Medical Group

**Minnesota**
- Abbott Northwestern Hospital*
- Buffalo Hospital
- Cambridge Medical Center
- CHI St. Gabriel’s Health
- Crosstown Surgery Center
- Cuyuna Regional Medical Center
- Douglas County Hospital
- Essentia Health-St. Mary’s Medical Center
- HealthEast Clinic - Woodwinds
- HealthEast St. John’s Hospital
- HealthEast St. Joseph’s Hospital
- Hennepin County Medical Center
- High Pointe Surgery Center
- Lakeview Hospital
- Mercy Hospital
- Mercy Hospital - Unity Campus
- New Ulm Medical Center
- Orthopaedic & Fracture Clinic
- Owatonna Hospital
- Park Nicollet Methodist Hospital
- Regina Hospital
- Regions Hospital
- Ridgeview Medical Center
- Riverwood Healthcare Center
- St. Francis Regional Medical Center
- Two Twelve Surgery Center
- United Hospital
- Vadnais Heights Surgery Center*
- WestHealth Surgery Center
- Abbott Northwestern - WestHealth

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Mississippi
Baptist Medical Center
Merit Health River Oaks
Singing River Hospital
St. Dominic Hospital
University of Mississippi Medical Center
Columbus Orthopaedic Outpatient Center
Mississippi Valley Surgery Center and Endoscopy Center
North Mississippi Medical Center
Ocean Springs Hospital
Specialty Surgical Center

Montana
Benefis Health System
St. Patrick Hospital
Providence St. Joseph Medical Center

Nebraska
CHI Health Immanuel
CHI Health Lakeside
CHI Health Midlands
Creighton University Medical Center - Bergan Mercy
Lincoln Surgical Hospital
Nebraska Medicine
Nebraska Orthopaedic Hospital
CHI Health Good Samaritan
CHI Health St. Elizabeth
Columbus Community Hospital
Creighton University Medical Center
Great Plains Health

Nevada
Renown Regional Medical Center
Centennial Hills Hospital Medical Center
Desert Springs Hospital
Henderson Hospital
MountainView Hospital
Northern Nevada Medical Center
Orthopaedic Institute of Henderson
Renown South Meadows Medical Center
Southern Hills Hospital & Medical Center
Spring Valley Hospital Medical Center
Summerlin Hospital Medical Center
Sunrise Hospital & Medical Center
Valley Hospital Medical Center

New Hampshire
Concord Hospital
Dartmouth-Hitchcock Medical Center
Concord Orthopaedics
Portsmouth Regional Hospital

New Jersey
Chilton Medical Center
Hackensack University Medical Center*
Morristown Medical Center
Newton Medical Center
Overlook Medical Center
Robert Wood Johnson University Hospital New Brunswick
St. Peter’s University Hospital
The Valley Hospital
Virtua Marlton Hospital
Virtua Memorial Hospital
Virtua Voorhees Hospital

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MercyOne Oakland Medical Center
Midwest Surgical Hospital

Mercy Orthopaedic & Rehabilitation Hospital
North Kansas City Hospital
Phelps County Regional Medical Center
Signature Medical Group
St. Luke’s Hospital
CoxHealth
Mercy Hospital Fort Smith
Metropolitan Orthopedics
Orthopedic Associates
Pawsat, MD & Maeda, MD P.C.
Saint Luke’s East Hospital*
Saint Luke’s Surgicenter-Lee’s Summit, LLC
St. Joseph Outpatient Surgery Center, LLC
St. Luke’s Hospital - Chesterfield
The Surgical Center at Columbia Orthopaedic Group
Truman Medical Center - Lakewood*

Missouri
Mercy Hospital Carthage
Mercy Hospital Jefferson
Mercy Hospital Joplin
Mercy Hospital Lebanon
Mercy Hospital Lincoln
Mercy Hospital South
Mercy Hospital Springfield
Mercy Hospital St. Louis
Mercy Hospital Washington
Mercy Orthopedic Hospital Springfield

AAOS American Joint Replacement Registry 2019 Annual Report 75
Institutions that submitted data for this Annual Report are highlighted in blue.

New Mexico

Memorial Medical Center - Las Cruces
 MountainView Regional Medical Center
 Presbyterian Hospital
 Presbyterian Rust Medical Center
 UNM Sandoval Regional Medical Center

New York

Crouse Hospital
 Glen Falls Hospital
 Hospital for Special Surgery
 Huntington Hospital*
 John T. Mather Memorial Hospital
 Kenmore Mercy Hospital
 Montefiore Medical Center
 Mount Sinai Brooklyn
 Mount Sinai Queens
 Mount Sinai St. Luke’s
 Mount Sinai West
 Newark-Wayne Community Hospital
 NewYork-Presbyterian Brooklyn Methodist Hospital
 NewYork-Presbyterian Queens
 NewYork-Presbyterian/Columbia University Irving Medical Center
 Rochester General Hospital*
 St. Charles Hospital*
 St. Francis Hospital
 St. Joseph’s Hospital Health Center
 St. Peter’s Hospital
 The Hospital for Joint Diseases
 The Mount Sinai Hospital
 UHS Binghamton General Hospital
 UHS Wilson Medical Center
 Unity Hospital*
 Upstate University Hospital - Community Campus
 Upstate University Hospital - Downtown Campus
 Winthrop-University Hospital
 Albany Memorial Hospital
 Elmhurst Hospital Center*
 Excelsior Orthopaedics
 Highland Hospital
 Lenox Hill Hospital*
 Long Island Jewish Forest Hills
 Long Island Jewish Medical Center*
 Long Island Jewish Valley Stream
 Maimonides Medical Center
 Mercy Hospital of Buffalo
 Mohawk Valley Health System
 Mount St. Mary’s Hospital and Health Center
 NewYork-Presbyterian Lower Manhattan Hospital
 NewYork-Presbyterian/Weill Cornell Medical Center
 North Shore University Hospital*
 Northern Westchester Hospital
 NYC Health + Hospitals/Elmhurst
 Oswego Hospital
 Peconic Bay Medical Center
 Phelps Hospital
 Plainview Hospital
 Saint Mary’s Hospital
 Sisters of Charity Hospital
 Sisters of Charity Hospital, St. Joseph Campus
 Southside Hospital
 Staten Island University Hospital
 Syosset Hospital
 Wyoming County Community Health System*

North Carolina

Blue Ridge Surgery Center
 Cone Health Wesley Long Hospital
 Davie Medical Center*
 FirstHealth Moore Regional Hospital
 Greensboro Orthopaedics
 Lexington Medical Center
 Mission Hospital
 Moses H. Cone Memorial Hospital
 New Hanover Regional Medical Center
 North Carolina Specialty Hospital
 Northern Hospital of Surry County
 Novant Health Brunswick Medical Center
 Novant Health Charlotte Orthopaedic Hospital
 Novant Health Forsyth Medical Center
 Novant Health Huntersville Medical Center
 Novant Health Matthews Medical Center
 Novant Health Rowan Medical Center

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<th>Institutions</th>
<th>Institutions</th>
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<td>Indu and Raj Soin Medical Center</td>
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<td>WakeMed Cary Hospital</td>
<td>McCullough-Hyde Memorial Hospital</td>
<td>Mercy Health - West Hospital</td>
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<td>Medina Hospital</td>
<td>Mercy Health Anderson Hospital</td>
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<td>WakeMed Raleigh Campus</td>
<td>Mount Carmel East</td>
<td>Mercy Health Clermont Hospital</td>
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<td>Mount Carmel New Albany</td>
<td>Mercy Health Fairfield Hospital</td>
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<td>Mount Carmel St. Ann’s</td>
<td>MetroHealth System</td>
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<td>Northside Regional Medical Center</td>
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<td>Carolina Sports Medicine &amp; Orthopaedic Specialists</td>
<td>OhioHealth Mansfield Hospital</td>
<td>Ohio Valley Surgical Hospital</td>
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<tr>
<td>Cary Orthopaedics</td>
<td>Selby General Hospital</td>
<td>Southview Medical Center</td>
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<tr>
<td>Cone Health Annie Penn Hospital</td>
<td>South Pointe Hospital</td>
<td>Southwest General Health Center</td>
</tr>
<tr>
<td>EmergeOrtho - Triangle Orthopedic Associates</td>
<td>St. Vincent Medical Center (Sisters of Charity - OH)</td>
<td>Sycamore Medical Center</td>
</tr>
<tr>
<td>Novant Health Clemmons Medical Center</td>
<td>The Ohio State University Wexner Medical Center</td>
<td>The Jewish Hospital - Mercy Health</td>
</tr>
<tr>
<td>Novant Health Kernersville Medical Center</td>
<td>TriHealth Evendale Hospital</td>
<td><strong>Oklahoma</strong></td>
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<tr>
<td>Novant Health UVA Prince William Medical Center</td>
<td>Trumbull Regional Medical Center*</td>
<td>Community Hospital North Campus</td>
</tr>
<tr>
<td>The Surgical Center of Morehead City</td>
<td>UH Ahuja Medical Center</td>
<td>Community Hospital South Campus</td>
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<tr>
<td>Viewmont Surgery Center</td>
<td>UH Bedford Medical Center, a campus of Regional Hospitals</td>
<td>Duncan Regional Hospital</td>
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<tr>
<td><strong>North Dakota</strong></td>
<td>UH Cleveland Medical Center*</td>
<td>Mercy Hospital Ada</td>
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<tr>
<td>Sanford Medical Center Fargo</td>
<td>UH Conneaut Medical Center</td>
<td>Mercy Hospital Ardmore*</td>
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<tr>
<td>CHI St. Alexius Health Bismarck*</td>
<td>UH Elyria Medical Center</td>
<td>Mercy Hospital Oklahoma City</td>
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<td></td>
<td>UH Geauga Medical Center</td>
<td>Northwest Surgical Hospital</td>
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<td></td>
<td>UH Geneva Medical Center</td>
<td>Southwestern Medical Center*</td>
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<td></td>
<td>UH Parma Medical Center</td>
<td>St. John Broken Arrow</td>
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<td></td>
<td>UH Portage Medical Center</td>
<td>Stillwater Medical Center</td>
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<td></td>
<td>UH Richmond Medical Center, a campus of Regional Hospitals</td>
<td>St. Mary’s Regional Medical Center*</td>
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<td>UH St. John Medical Center</td>
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<td></td>
<td>Adena Regional Medical Center*</td>
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<td></td>
<td>Amherst Family Health Center</td>
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<td></td>
<td>Ashtabula County Medical Center</td>
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<td></td>
<td>Cleveland Clinic Children’s Hospital for Rehabilitation</td>
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<td>Cleveland Clinic Fairview Hospital</td>
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<tr>
<td></td>
<td>First Settlement Orthopaedics</td>
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<tr>
<td></td>
<td>Fort Hamilton Hospital</td>
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</tr>
</tbody>
</table>

*Achieved The Joint Commission Advanced Certification for Total Hip and Total Knee Replacement*
Institutions that submitted data for this Annual Report are highlighted in blue.

Providence Newberg Medical Center
Providence Portland Medical Center
Providence Seaside Hospital
Providence St. Vincent Medical Center
Providence Willamette Falls Medical Center
Salem Health
Samaritan Albany General Hospital
St. Alphonsus Medical Center Baker City
St. Alphonsus Medical Center Ontario
St. Charles Health System
Tillamook Regional Medical Center
Willamette Valley Medical Center*
Williamette Surgery Center*
Bend Surgery Center
CHI Mercy Health Mercy Medical Center
Hope Orthopedics of Oregon
Legacy Emanuel Medical Center
Legacy Good Samaritan Medical Center
Legacy Meridian Park Medical Center
Legacy Mount Hood Medical Center
Oregon Orthopedic & Sports Medicine Clinic
Portland Knee Clinic
South Portland Surgical Center

Penn Highlands Healthcare
Penn Presbyterian Medical Center
Penn State Milton S. Hershey Medical Center
Pennsylvania Hospital
Reading Hospital*
Regional Hospital of Scranton*
St. Mary Medical Center
UPMC Altoona
UPMC East
UPMC Hamot
UPMC Hanover
UPMC Horizon
UPMC Jameson
UPMC Magee-Womens Hospital
UPMC McKeesport
UPMC Mercy
UPMC Northwest
UPMC Passavant - McCandless
UPMC Pinnacle Community Osteopathic
UPMC Pinnacle Harrisburg
UPMC Pinnacle West Shore
UPMC Presbyterian
UPMC Shadyside
UPMC St. Margaret
WellSpan Gettysburg Hospital
WellSpan Surgery & Rehabilitation Hospital
WellSpan York Hospital
Abington Memorial Hospital*
Allegheny General Hospital
Chan Soon-Shion Medical Center at Windber
Conemaugh Memorial Medical Center*
Excela Health Latrobe Hospital
Excela Health Westmoreland Hospital
Health Services UHS Campus
Lansdale Hospital*

Mercy Catholic Medical Center – Mercy Philadelphia Campus
Mercy Fitzgerald Hospital
Monongahela Valley Hospital*
Muve - Warminster Ambulatory Surgical Center, LLC
OSS Orthopaedic Hospital
Phoenixville Hospital*
Richards Orthopaedics Center & Sports Medicine
Rothman Orthopaedic Institute at Jefferson
Surgery Center of Allentown
The Hospital of the University of Pennsylvania
Thomas Jefferson University Hospital
UPMC Carlisle
UPMC Children’s Hospital of Pittsburgh
UPMC Memorial
UPMC Pinnacle
UPMC Pinnacle Lititz

Rhode Island
South County Hospital
Yale New Haven Health Westerly Hospital
The Miriam Hospital*

South Carolina
Bon Secours St. Francis Hospital
Carolina Pines Regional Medical Center
East Cooper Medical Center*
Medical University of South Carolina*
Palmetto Health Baptist
Palmetto Health Richland
Providence Orthopedic Hospital
Roper St. Francis Hospital
Roper St. Francis Mount Pleasant Hospital
Self Regional Medical Center

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- Baptist Easley Hospital
- Beaufort Memorial Hospital
- Carolina Coast Surgery Center
- Carolina Orthopedics
- Conway Medical Center
- GHS Patowood Memorial Hospital*
- Grand Strand Medical Center
- Novant Health Gaffney Medical Center
- Oconee Memorial Hospital
- Prisma Health Baptist Parkridge Hospital
- Trident Medical Center

**South Dakota**
- Sanford USD Medical Center
- Dunes Surgical Hospital

**Tennessee**
- Baptist Memorial Hospital-Collierville
- CHI Memorial Hospital Chattanooga
- Erlanger Baroness Hospital
- Erlanger East Hospital
- Henry County Medical Center
- Indian Path Community Hospital
- Johnson City Medical Center
- Maury Regional Medical Center
- Physicians Regional Medical Center
- Saint Thomas Midtown Hospital
- Saint Thomas West Hospital
- Tennessee Orthopaedic Alliance
- University of Tennessee Medical Center*
- Bristol Regional Medical Center*
- CHI Memorial Hospital Hixson
- Claiborne Medical Center
- Cumberland Medical Center
- Fort Loudoun Medical Center
- Fort Sanders Regional Medical Center
- Huntsville Hospital
- LeConte Medical Center
- Methodist Medical Center of Oak Ridge
- Mid-Tennessee Bone & Joint Clinic, P.C.
- Morristown-Hamblen Healthcare System
- OrthoTennessee
- Parkridge East Hospital
- Parkridge Medical Center
- Parkwest Medical Center
- Premier Orthopedic Surgery Center
- Roane Medical Center
- Saint Thomas Rutherford Hospital
- St. Francis Hospital
- TriStar Centennial Medical Center
- TriStar Hendersonville Medical Center
- TriStar Horizon Medical Center
- TriStar Skyline Medical Center
- TriStar Southern Hills Medical Center
- TriStar StoneCrest Medical Center
- TriStar Summit Medical Center
- Turkey Creek Medical Center

**Texas**
- Ascension Seton Hays
- Ascension Seton Medical Center Austin
- Ascension Seton Northwest Hospital
- Ascension Seton Southwest
- Ascension Seton Williamson
- Baptist Beaumont Hospital of Southeast Texas
- Baylor Scott & White All Saints Medical Center - Fort Worth
- Baylor Scott & White Medical Center - Carrollton
- Baylor Scott & White Medical Center - Frisco
- Baylor Scott & White Medical Center - Garland
- Baylor Scott & White Medical Center - Grapevine
- Baylor Scott & White Medical Center - Irving
- Baylor Scott & White Medical Center - McKinney
- Baylor Scott & White Medical Center - Plano
- Baylor Scott & White Medical Center - Waxahachie
- Baylor University Medical Center
- CHRISTUS Good Shepherd Medical Center - Longview*
- CHRISTUS Good Shepherd Medical Center - Marshall
- CHRISTUS Mother Frances Hospital - Tyler*
- CHRISTUS Southeast Texas Hospital - St. Elizabeth
- College Station Medical Center
- Collom & Carney Clinic Association
- Covenant Children’s Hospital
- Covenant Health Plainview
- Covenant Medical Center
- Covenant Specialty Hospital
- Dallas Orthopedic & Shoulder Institute
- Dell Seton Medical Center at The University of Texas
- Doctors Hospital at Renaissance*
- El Paso Specialty Hospital
- Harlingen Medical Center
- Houston Methodist Hospital
- JPS Health Network
- Memorial Hermann Memorial City Medical Center
- Memorial Hermann Southwest Hospital
- Midland Memorial Hospital
- Nix Health
- North Central Surgical Center Hospital
- Paris Orthopedics & Sports Medicine
- Scott & White Memorial Hospital - Temple

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Seton Highland Lakes Hospital
South Texas Spine and Surgical Hospital
South Texas Surgical Hospital
St. Joseph Health System
Texas Health Harris Methodist Hospital Southwest Fort Worth
Texas Health Presbyterian Hospital Flower Mound
Texas Health Presbyterian Hospital Plano
Texas Health Presbyterian Hospital Rockwall
Texas Institute for Surgery
The Carrell Clinic
United Regional Health Care System*
UT Southwestern Medical Center
Advent Orthopaedics
Baylor Scott & White Medical Center - Uptown
Baylor Surgical Hospital at Las Colinas
CHRISTUS Mother Frances Hospital
Cornerstone Regional Hospital*
Corpus Christi Medical Center
Covenant Hospital Levelland
Cross Timbers Orthopedics
Del Sol Medical Center
Doctors Hospital of Laredo
Edinburg Regional Medical Center
Fort Duncan Regional Medical Center
HCA Houston Healthcare Clear Lake
Hill Country Memorial Hospital
Jeff Zhao, DO
Las Palmas Medical Center
McAllen Medical Center
Medical City Dallas Hospital
Medical City Denton
Memorial Hermann Orthopedic & Spine Hospital
Methodist Hospital
Methodist McKinney Hospital, LLC
Methodist Stone Oak Hospital
Methodist Texsan Hospital
Metropolitan Methodist Hospital
Muve - Lakeway Ambulatory Surgical Center, LLC*
Northeast Baptist Hospital
Northeast Methodist Hospital
Northwest Texas Healthcare System
Seton Medical Center Harker Heights*
St. David's Georgetown Hospital
St. David's Medical Center
St. David's North Austin Medical Center
St. David's Round Rock Medical Center
St. David's South Austin Medical Center
St. David's Surgical Hospital
Stefan Kreuzer
Texas Health Surgery Center Cleburne
Texas Orthopaedic Associates
Texas Orthopedics, Sports & Rehabilitation Associates
Texas Orthopedic Dallas
Texas Orthopedic Hospital
Texas Spine and Joint Hospital
Texoma Medical Center
The Physicians Centre Hospital
W.B. Carrell Clinic
Maple Grove Hospital
McKay-Dee Hospital*
North Memorial Health Hospital
Park City Hospital
Primary Children’s Hospital
Riverton Hospital
Sevier Valley Hospital
TOSH - The Orthopedic Specialty Hospital
University of Utah Health
Utah Valley Hospital
Cassa Regional Hospital
Cedar Orthopedic Surgery Center
Lakeview Hospital*
Layton Hospital
McKay-Dee Surgical Center
Mountain View Hospital
Ogden Regional Medical Center
Orem Community Hospital
St. Mark's Hospital
Timpanogos Regional Hospital

Vermont
Central Vermont Medical Center
Rutland Regional Medical Center
The University of Vermont Medical Center
Northwestern Medical Center

Virginia
Carilion New River Valley Medical Center
Carilion Roanoke Memorial Hospital
Inova Fair Oaks Hospital
Inova Loudoun Hospital
Inova Mount Vernon Hospital
Johnston Memorial Hospital
Mary Washington Hospital
Novant Health Prince William Medical Center

Utah
Altaview Hospital
American Fork Hospital
Bear River Valley Hospital
Cedar City Hospital
Dixie Regional Medical Center
Heber Valley Hospital
Intermountain Medical Center
LDS Hospital
Logan Regional Hospital

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Novant Health UVA Haymarket Medical Center
Reston Hospital Center*
Sentara CarePlex Hospital
Sentara Leigh Hospital
Sentara Martha Jefferson Hospital
Sentara Norfolk General Hospital
Sentara Northern Virginia Medical Center
Sentara Obici Hospital
Sentara Princess Anne Hospital
Sentara RMH Medical Center
Sentara Virginia Beach General Hospital
Sentara Williamsburg Regional Medical Center
University of Virginia Health System University Hospital
Virginia Hospital Center
CJW Medical Center
Henrico Doctors’ Hospital
Inova Fairfax Hospital
OrthoVirginia
Riverside Doctors’ Hospital Williamsburg
Riverside Regional Medical Center
Riverside Tappahannock Hospital
Riverside Walter Reed Hospital
Proliance Center for Outpatient Spine and Joint Surgery of Puget Sound
Proliance Eastside Surgery Center
Proliance Highlands Surgery Center
Providence Centralia Hospital
Providence Holy Family Hospital - Spokane
Providence Mount Carmel Hospital
Providence Regional Medical Center Everett Colby Campus
Providence Sacred Heart Medical Center
Providence St. Joseph’s Hospital
Providence St. Mary Medical Center
Providence St. Peter Hospital
Seattle Orthopedic Center Surgery
Seattle Surgery Center
Skagit Northwest Orthopedics
St. Anthony Hospital
St. Clare Hospital
St. Elizabeth Hospital
St. Francis Hospital
St. Joseph Medical Center
Swedish Health Ballard Campus
Swedish Health Edmonds Campus
Swedish Health First Hill Campus
Swedish Health Issaquah Campus
The Surgery Center at Rainier
Trios Health
Valley Medical Center
Virginia Mason Medical Center
Walla Walla General Hospital
Yakima Valley Memorial Hospital
Dan Downey, MD
Edmonds Center for Outpatient Surgery
Legacy Salmon Creek Medical Center
MultiCare Allenmore Hospital & Medical Center
MultiCare Auburn Medical Center
MultiCare Covington Medical Center
MultiCare Deaconess Hospital
MultiCare Good Samaritan Hospital
MultiCare Tacoma General Hospital
Multicare Valley Hospital*
Olympia Surgery Center
Providence Regional Medical Center Everett Pacific Campus
Southwest Seattle Ambulatory Surgery Center
Wenatchee Hospital & Clinic

West Virginia
Cabell Huntington Hospital*
Ruby Memorial Hospital
West Virginia University Hospital*

Wisconsin
Amery Hospital & Clinic
Ascension St. Mary’s Hospital
Ascension St. Michael’s Hospital
Aurora BayCare Medical Center
Aurora Lakeland Medical Center
Aurora Medical Center in Grafton
Aurora Medical Center in Kenosha
Aurora Medical Center in Manitowoc County
Aurora Medical Center in Oshkosh
Aurora Medical Center in Summit
Aurora Medical Center in Washington County
Aurora Memorial Hospital of Burlington
Aurora Sinai Medical Center
Aurora St. Luke’s Medical Center
Aurora St. Luke’s South Shore of Aurora Health Care Metro, Inc.
Aurora West Allis Medical Center
Beaver Dam Community Hospitals
Beloit Memorial Hospital*
Berlin Memorial Hospital

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Columbus Community Hospital
Community Memorial Hospital*
Fort Healthcare
Froedert Hospital
Gundersen Health System
HSHS St. Mary’s Hospital Medical Center
HSHS St. Nicholas Hospital
HSHS St. Vincent Hospital
Hudson Hospital & Clinic
Lakeview Medical Center
Mercyhealth Hospital & Trauma Center
Mercyhealth Hospital and Medical Center - Walworth
Monroe Clinic Hospital
OakLeaf Surgical Hospital
Oconomowoc Memorial Hospital
Orthopedic & Sports Surgery Center
Orthopedic Hospital of Wisconsin
Osceola Medical Center
ProHealth Waukesha Memorial Hospital
Ripon Medical Center
River Falls Area Hospital
Sauk Prairie Hospital
Southwest Health
St. Agnes Hospital
St. Croix Regional Medical Center
St. Joseph's Hospital, West Bend
ThedaCare Medical Center-New London
ThedaCare Medical Center-Shawano
ThedaCare Medical Center-Waupaca
ThedaCare Regional Medical Center-Appleton
ThedaCare Regional Medical Center-Neenah
Tomah Memorial Hospital
UnityPoint Health - Meriter
University of Wisconsin Hospitals and Clinics
Vernon Memorial Healthcare
Waupun Memorial Hospital
Westfields Hospital & Clinic
Ascension All Saints Hospital - Spring Street Campus
Aspirus Health Care
Aurora Medical Center in Milwaukee
Aurora Sheboygan Memorial Medical Center

Divine Savior Healthcare
Froedert Community Memorial Hospital
Hayward Area Memorial Hospital
Lakeview Hospital
Marshfield Medical Center - Neillsville
Memorial Medical Center
Midwest Orthopedic Specialty Hospital
Orthopedic & Sports Medicine Specialists of Green Bay
SSM Health St. Clare Hospital - Baraboo
SSM Health St. Clare Hospital - Janesville
SSM Health St. Mary’s Hospital - Madison
St. John’s Hospital

**Wyoming**
Cheyenne Regional Medical Center
Mountain View Regional Hospital
St. John’s Medical Center

Fairview Lakes Medical Center

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Appendix F

2019 AJRR Annual Report Clinical Survivorship Curve Methodology

All AJRR patients undergoing a primary total joint replacement or revision surgery were identified using International Classification of Disease (ICD) -9/10 and Current Procedural Terminology (CPT) codes in both the AJRR and the Centers for Medicare & Medicaid Services (CMS) dataset. Revisions were “linked” to primary when known laterality was the same for both a primary when revision surgery and the revision procedure postdated the primary procedure. AJRR collects a discrete laterality data element. Since ICD-9 does not identify laterality, but ICD-10 does, when laterality was in question, it was cross-referenced with AJRR data as well as the modifiers LT and RT from CPT codes as provided in AJRR and the CMS data.

For ICD-9 codes, the assumption was made that a revision code postdating a primary procedure was a “linked” revision, which was later validated in the AJRR database. ICD-10 coding allows for (but does not require) both removal and replacement codes, but has the advantage of including laterality. The same postdating assumptions were made with either acceptable single codes for revision or with the dual code permutations. In short, appropriate laterality was used to identify revisions and primaries when ICD-10 coding was used and, when ICD-9 was used, subsequent revisions were linked to previous primary procedures with laterality verified at a later step.

Patients were tracked for the data set of 2012-2018. Their follow-up was from time of procedure until 12/31/2018 and the primary time-scale was “months to revision.” Patients were tracked for potential outcomes (e.g., death, dislocation, and instability) from the procedure date until 12/31/2018. Patients were right censored if they did not have the outcome of interest. Death was identified from the National Death Index (2012-2016) or AJRR data (collected as an optional discrete data element, 2012-2018).

Primary procedures were counted as failed and the survivorship recorded if revision was identified or found within either the AJRR or Medicare dataset. Failure of the primary arthroplasty was the outcome, unless specified otherwise.

The CMS Research Data Assistance Center (ResDAC) data team provided AJRR with a unique identifier that matches an AJRR case record to a CMS claim file. Observations from ICD-9 codes where patients were noted to have mismatched laterality for primary and revision or revisions without a previous record of a primary in the AJRR database were excluded. When laterality remained unknown after these methods, the primary and revision procedures were not “linked” and were subsequently removed from analyses. A merged AJRR and CMS dataset was used for all survivorship analyses unless otherwise specified.

Semi-parametric Cox proportional hazard regression models were used to construct survival curves adjusted for age and sex (where appropriate) and stratified by a number of surgical details and implant characteristics. Direct adjustment methods were used to produce adjusted survival curves based on the empirical age and sex distribution of the full dataset. 95% confidence intervals were computed for the entire adjusted survival curves and are graphically represented. When comparing groups, the 95% confidence intervals and p-values of the hazard ratios were used to determine statistical significance.

When interpreting any survivorship curve produced, it is important to consider that these analyses represent retrospective observational data from a large registry and administrative database. Therefore, causation cannot be established and only associations are offered. Based off any association likely further analyses are needed to appropriately determine the root cause.

SAS Version 9.4 was used for all statistical analyses.


At the time of publication, every effort was made to ensure the information contained in this report was accurate. The document is available for download at www.aaos.org/ajrr.

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