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Causes of Early Hip Revision Vary by Age and Gender: Analysis of Data From a Statewide Quality Registry

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ABSTRACT

Background: While total hip arthroplasty (THA) is extremely successful, early failures do occur. The purpose of this study was to determine the cause of revision in specific patient demographic groups at 3 time points to potentially help decrease the revision risk.
Methods: Data for cases performed between 2012 and 2018 from a statewide, quality improvement arthroplasty registry were used. The database included 79,205 THA cases and 1,433 revisions with identified etiology (1,584 in total). All revisions performed at <5 years from the primary THA were reviewed. Six groups, men/women, <65, 65-75, and >75 years, were compared at revision time points <6 months, <1 year, and <5 years.
Results: There were obvious and significant differences between subgroups based on demographics and time points ($P < .0001$). Seven hundred and fifty-six (53%) of all revisions occurred within 6 months. The most common etiologies within 6 months (756 revisions) were fracture (316, 41.8%), dislocation/instability (194, 25.7%), and infection (98, 12.9%). At this early time point, the most common revision cause was fracture for all age/gender-stratified groups, ranging from 27.6% in young men to 60% in older women. Joint instability became the leading cause for revision after 1 year in all groups.
Conclusion: This quality improvement project demonstrated clinically meaningful differences in the reason for THA revision between gender, age, and time from surgery. Strategies based on these data should be employed by surgeons to minimize the factors that lead to revision.

The literature is inconclusive as to the most common cause of total hip arthroplasty (THA) failure leading to revision, both early and late. The most commonly cited causes of revision are instability [1–5], aseptic loosening [6–8], periprosthetic femur fracture [9,10], or periprosthetic joint infection [11,12], with many different risk factors cited for each [13–19]. This heterogeneity highlights the need for further study and the utility of large multicenter databases. Large registries in the United States and worldwide, such as the American Joint Replacement Registry (AJRR) and the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), for example, can be used to synthesize high volume data over many hospital systems to identify trends in treatment and complications [20–22]. Registry data are expected to be evermore useful in driving improvements in patient care [23–26].

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The Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI) is a consortium that consists of more than 64 participating hospitals and 15 ambulatory surgery centers in the state of Michigan focused on total joint arthroplasty (TJA) [27]. The stated goals include improving patient safety and quality of TJA procedures through an analysis of registry data [27]. MARCQI captures data on more than 96% of all elective arthroplasty cases performed in the state of Michigan and has more than 370,000 fully abstracted cases. All data points are specifically obtained by trained nurse abstractors at each participating clinical site.

As a quality improvement project, MARCQI data were used to evaluate and determine the most common causes for hip revision surgery overall and within 6 specific patient subgroups at 3 differing time points. The goal was to improve the quality by recognizing risk factors for the specific subgroups to guide treatment regimens and choice of implant when performing THA.

Methods and Statistical Analysis

All data were obtained from the MARCQI database [28]. Despite having a determination of 'not regulated' under 45 CFR (US Department of Health and Human Services 'Code of Federal Regulations') 46 by the University of Michigan's Institutional Review Board, an additional institutional review board exemption was obtained from the Beaumont Health (Royal Oak, MI). Data for THA cases performed between February 2012 and December 2018 were used for an analysis. All revisions performed within 5 years from their index primary procedure were reviewed. The distribution of variables was examined and determined prior to the analysis. Age was categorized into 3 subgroups: age less than 65 years, age between 65 and 75 years, and age older than 75 years. To determine the reason for revision at different time points, the time-to-revision after the index surgery was determined and the cases stratified into three subgroups: revision within 6 months, within 1 year, and within 5 years, respectively. The reasons for revision were determined overall and based on the stratified data by gender and age group and the top 3 reasons for revisions in each subgroup were reported. The reasons for new revision cases within each time period exclusive of the other time periods ie, <6 months, 6 months to 1 year, 1 year to 5 years, were also explored. The trends of reasons for revision were visualized using line graphs. The trends of the top 3 reasons identified in each subgroup were also plotted. The Chi-square testing was used to evaluate data distribution and to determine whether observed differences in revision causes among and between groups carried statistical significance. *P* values of less than .05 were considered significant.

Note: Support for the Michigan Arthroplasty Registry Collaborative Quality Initiative is provided by Blue Cross Blue Shield of Michigan and Blue Care Network as part of the Blue Cross and Blue Shield of Michigan (BCBSM) Value Partnerships Program. Although Blue Cross Blue Shield of Michigan and the Michigan Arthroplasty Registry Collaborative Quality Initiative work collaboratively, the opinions, beliefs, and viewpoints expressed by the author do not necessarily reflect the opinions, beliefs, and viewpoints of BCBSM or any of its employees.

Results

At the time of the study, the database included 79,205 elective THA cases and 1,433 revisions with identified reasons (1,570 revisions in total).

The mean age and body mass index (BMI) for the study population were 64.8 and 30.5, respectively. Overall there were 43,144 (54.5%) THA cases in females and 36,041 (45.5%) THA cases in males. Twenty (0.03%) cases were lacking an identified gender and were excluded from the analysis. Descriptive demographic statistics of all THA cases included in the study are shown in Table 1.

Table 1
Demographic Data; n = 79,205.

Variables	Mean (Standard Deviation [SD]) or N (%)
Age	Mean (SD) = 64.8 (11.1)
BMI	Mean (SD) = 30.5 (6.3)
Smoking	
Never-smokers	37,550 (47.4%)
Previous smokers	30,503 (38.5%)
Current smokers	10,778 (13.6%).
Gender	
Female	43,144 (54.47%)
Male	36,041 (45.50%)
Missing/Unknown	20 (0.03%)
Age	
<65	37,968 (47.94%)
65~75	25,606 (32.33%)
75+	15,631 (19.73%)
Gender by Age	
Female <65	18,339 (23.16%)
Male <65	19,618 (24.77%)
Female (65~75)	14,934 (18.86%)
Male (65~75)	10,666 (13.47%)
Female 75+	9,871 (12.47%)
Male 75+	5,757 (7.27%)

There were 1,433 total revision THAs with an identified reason, which was broken down by age group and time period (Table 2). Of the 1,433 identified revisions, 756 (52.8%) occurred in the first 6 months following the index procedure, 961 (67.1%) occurred within one year, and 1,419 (99%) within 5 years. The 14 (<1%) revisions that occurred >5 years after the index procedure were not included in further analysis. The Younger Female group had the highest total number of revisions at all the time points, followed by Females aged 65-74 years and Younger Males within 6 months and Younger Males and Females aged 65-74 years within 1 year and 5 years, respectively.

The overall revision percentage for all reasons (including when no reason was identified) for each age group at each time point (Table 3) was significantly different across all groups ($P < .001$). Overall, 1.07% of all THAs were revised within 6 months of index procedure, 1.37% were revised within 1 year, and 1.98% within 5 years. Older Males had the highest percentage of revisions within 6 months (1.55%), followed by Older Females (1.49%) and Females aged 65-74 years (1.07%). Older Males also had the highest revision rate within 1 year (1.77%), followed by Younger Females (1.46%). Younger Females had the highest revision rate within 5 years (2.33%), followed by Older Males (2.24%) and Older Females (2.12%). Younger Males had the lowest rate of revision at all the time points (0.8%, 1.05%, and 1.6%, respectively).

The breakdown of the top 3 reasons for revision within each age/gender-stratified group during each defined time period is shown in Table 4. *P* values from Chi-square testing for all reasons for

Table 2
Number of Revisions with a Known Reason in Each Subgroup by Age and Gender. Total Known Revisions, n = 1,433.

	W/In 6 mo	W/In 1 y	W/In 5 y
Total revisions	756	961	1,419
Female age <65	154	217	366
Female 65-75	150	184	269
Female age >75	136	160	195
Male age <65	141	185	290
Male 65-75	93	121	180
Male age >75	82	94	119

Table 3
Percent of all Revisions in Each Subgroup by Age and Gender at Each Time Point. All Numbers Represent % Value.

	W/In 6 mo	W/In 1 y	W/In 5 y
Total revisions	1.07	1.37	1.98
Female age <65	1.02	1.46	2.33
Female 65-75	1.07	1.33	1.92
Female age >75	1.49	1.33	2.12
Male age <65	0.80	1.05	1.60
Male 65-75	1.01	1.34	1.91
Male age >75	1.55	1.77	2.24

revision and across only the top three reasons are shown. Differences across all reasons for revision were significant ($P < .05$) in every group except Older Females 1 year to 5 years ($P = .0536$) and Older Males 6 months to 1 year ($P = .429$). Overall, 756 (52.76%) of the 1,433 total revisions occurred within the first 6 months following the index procedure. Two hundred and five (14.31%) occurred in the 6 months to 1 year postindex procedure time period, whereas 458 (31.96%) occurred between 1-5 years postindex THA. The top reason for revision within 6 months overall was periprosthetic femur fracture, whereas the second most common reason was dislocation/instability. This was also true of all age/gender-stratified groups within 6 months except Males aged 65-75 years, for whom the second most prevalent reason for revision within 6 months was infection.

Joint infection became the most prevalent reason for revision overall in the 6 month to 1 year time period, whereas aseptic loosening and dislocation/instability were the second and third most-prevalent, respectively. Joint infection was in the top 2 reasons for revision in each of the stratified groups from 6 months to 1 year. Periprosthetic femur fracture was no longer in the top three reasons for revision in any group except for Males aged 75+ years.

Beyond 1 year postindex procedure, aseptic loosening was the most common reason for revision in all groups. After being the most common reason for revision in every group within 6 months, periprosthetic femur fracture was only in the top 3 reasons for three groups: Older Females 1 year to 5 years, Older Males 6 months to 1 year, and Older Males 1 year to 5 years. Overall incidence of joint infection decreased from the 6-month time period to the 6 month to 1 year period, despite becoming the most prevalent reason for revision, before increasing again in the 1 year to 5 years group. Aseptic loosening showed a steady increase in incidence as time progressed, whereas the incidence of dislocation/instability remained relatively constant as a percentage across time periods.

The trend of revision causes over time showed that the prevalence of fracture decreased after the first 6 months, whereas other causes increased in prevalence after 6 months. This is demonstrated graphically in Figure 1.

Discussion

Despite material and technological advances in primary THA, early failure and revision rates have not declined substantially [29]. Previous studies have shown that the incidence of revision surgery has increased in the United States [2]. This trend is predicted to

Table 4
Top 3 Reasons for Revision by Age and Gender. Total Revisions With Known Reasons, n = 1,433. *P* Values Shown for Chi-Square Testing Across all Reasons for Revision and Across Only the Top 3 Reasons for Revision, Respectively.

Sex/Gender groups	Rank	Top 3 Reasons Within 6 mo N = 756 (52.76%)		Top 3 Reasons 6 mo to 1 y N = 205 (14.31%)		Top 3 Reasons 1 y to 5 y N = 458 (31.96%)	
		Reasons	N (%)	Reasons	N (%)	Reasons	N (%)
Overall	1	Femur fracture	316 (41.8)	Joint Infection	66 (32.2)	Aseptic Loosening	146 (31.9)
	2	Dislocation/Instability	194 (25.7)	Aseptic Loosening	42 (20.5)	Dislocation/Instability	89 (19.4)
	3	Joint Infection	98 (12.9)	Dislocation/Instability	41 (20.0)	Joint Infection	80 (17.5)
	$P < .0001$ for all reasons			$P < .0001$ for all reasons		$P < .0001$ for all reasons	
	$P < .0001$ for top 3 reasons			$P = .0177$ for top 3 reasons		$P < .0001$ for top 3 reasons	
Female, age <65	1	Femur fracture	55 (35.7)	Dislocation/Instability	20 (31.8)	Aseptic Loosening	48 (32.2)
	2	Dislocation/Instability	46 (29.9)	Joint Infection	15 (23.8)	Dislocation/Instability	33 (22.2)
	3	Joint Infection	19 (12.3)	Pain	14 (22.2)	Pain	25 (16.8)
	$P < .0001$ for all reasons			$P < .0001$ for all reasons		$P < .0001$ for all reasons	
	$P = .0002$ for top 3 reasons			$P = .5312$ for top 3 reasons		$P = .0211$ for top 3 reasons	
Female, age 65~75	1	Femur fracture	77 (51.3)	Joint Infection	12 (35.3)	Aseptic Loosening	30 (35.3)
	2	Dislocation/Instability	38 (25.3)	Aseptic Loosening	6 (17.7)	Dislocation/Instability	27 (31.8)
	3	Aseptic Loosening	11 (7.3)	Dislocation/Instability	6 (17.7)	Joint Infection	15 (17.7)
	$P < .0001$ for all reasons			$P = .0077$ for all reasons		$P < .0001$ for all reasons	
	$P < .0001$ for top 3 reasons			$P = .2231$ for top 3 reasons		$P = .0724$ for top 3 reasons	
Female, age 75+	1	Femur fracture	82 (60.3)	Dislocation/Instability	9 (37.5)	Aseptic Loosening	10 (28.6)
	2	Dislocation/Instability	30 (22.1)	Joint Infection	6 (25)	Dislocation/Instability	8 (22.9)
	3	Joint Infection	7 (5.2)	Pain	4 (16.7)	Femur fracture	6 (17.14)
	$P < .0001$ for all reasons			$P = .0423$ for all reasons		$P = .0536$ for all reasons	
	$P < .0001$ for top 3 reasons			$P = .3679$ for top 3 reasons		$P = .6065$ for top 3 reasons	
Male, age <65	1	Femur fracture	39 (27.7)	Joint Infection	18 (40.9)	Aseptic Loosening	32 (30.5)
	2	Dislocation/Instability	39 (27.7)	Aseptic Loosening	15 (34.1)	Joint Infection	22 (20.9)
	3	Joint Infection	33 (23.4)	Pain	4 (9.1)	Dislocation/Instability	12 (11.4)
	$P < .0001$ for all reasons			$P < .0001$ for all reasons		$P < .0001$ for all reasons	
	$P = .7230$ for top 3 reasons			$P = .0122$ for top 3 reasons		$P = .0106$ for top 3 reasons	
Male, age 65~75	1	Femur fracture	27 (29.0)	Joint Infection	11 (39.3)	Aseptic Loosening	17 (28.8)
	2	Joint Infection	23 (24.7)	Aseptic Loosening	8 (28.6)	Joint Infection	14 (23.7)
	3	Dislocation/Instability	22 (23.7)	Dislocation/Instability	5 (17.9)	Dislocation/Instability	8 (13.6)
	$P < .0001$ for all reasons			$P = .0003$ for all reasons		$P < .0001$ for all reasons	
	$P = .7470$ for top 3 reasons			$P = .3247$ for top 3 reasons		$P = .1988$ for top 3 reasons	
Male, age 75+	1	Femur fracture	36 (43.9)	Femur Fracture	4 (33.3)	Aseptic Loosening	9 (36)
	2	Dislocation/Instability	19 (23.2)	Joint Infection	4 (33.3)	Femur fracture	6 (24)
	3	Joint Infection	11 (13.4)	Aseptic Loosening	2 (16.7)	Joint Infection	5 (20)
	$P < .0001$ for all reasons			$P = .4290$ for all reasons		$P = .0468$ for all reasons	
	$P = .0006$ for top 3 reasons			$P = .6703$ for top 3 reasons		$P = .5220$ for top 3 reasons	

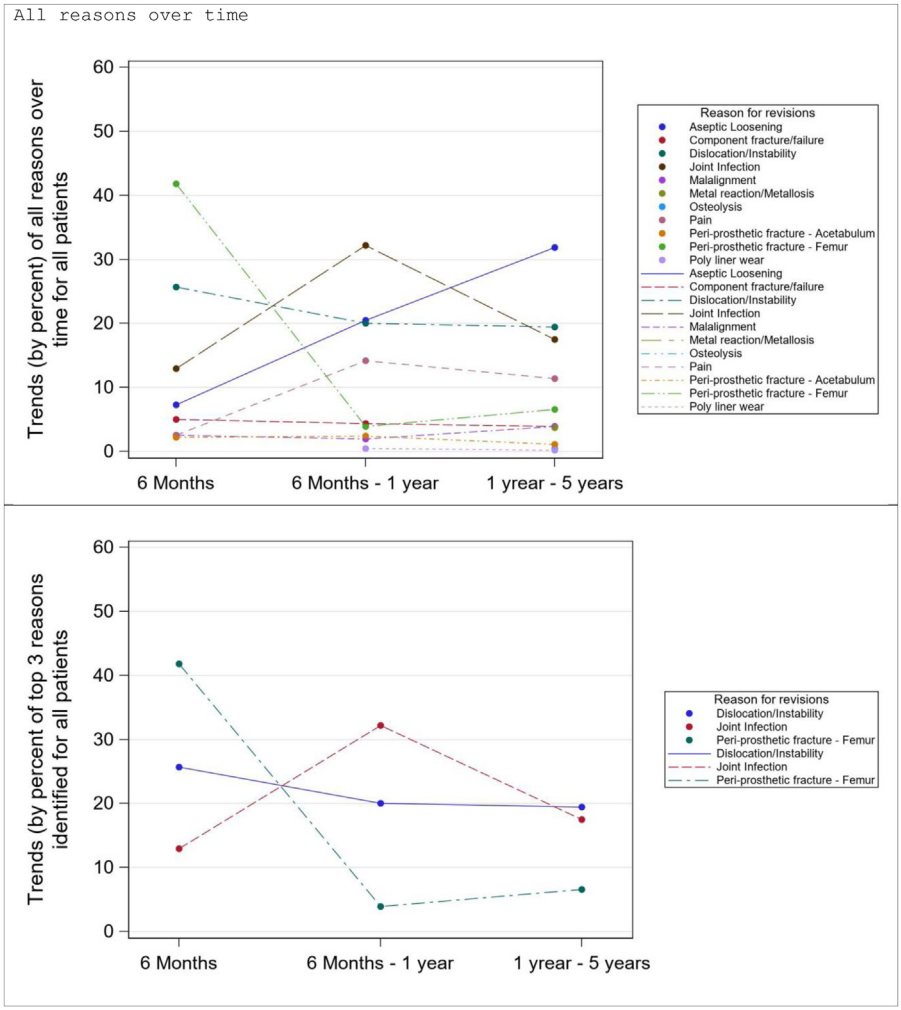

Fig. 1. Trends over time (by percentage) of reasons for revision among entire study population (top—all reasons; bottom—top 3 reasons as identified at 6 months).

continue, and the demand for hip revision procedures is projected to double by the year 2026, with an overall projection to grow by 13.7% between 2005 and 2030 [30–32]. The cost of revision surgery places a large economic burden of US healthcare, as the mean total cost of a revision surgery is nearly $78,000, [4] the total cost was $1.40 billion in 2003, and the mean economic burden was 18.8% [33].

Despite these persistent risks and economic burden, THA remains one of the most successful surgeries in orthopedics, with at least 93% patient satisfaction [34]. The number of primary THAs performed each year continues to grow. By 2030, the demand for primary THA is estimated to grow by 17.4% to 572,000 [30]. The demographics of THA are shifting as well. The age distribution of inpatients aged 45 years and older who received THAs changed drastically between 2000 and 2010, with the percentage of THAs increasing for younger age groups and decreasing for older age groups [35]. In light of this shifting landscape, it is not surprising that demographics differences are associated with different causes of revision. For these reasons, studying the causes for revision surgery by MARCQI was felt to be important to improve quality and patient care for the consortium hospitals and the orthopedic community at large.

The overall revision rate for the MARCQI study's population was 1.98% after 5 years. Importantly, more than half of the revisions occurred within the first 6 months (the vast majority of these within 6 weeks). These revision rates are not dissimilar to other studies that evaluated an early revision [29,36]. Historically, aseptic loosening and/or dislocation have been cited as more prevalent causes of revision than fracture [1–8]. Likewise, some studies examining only early causes of revision have identified aseptic loosening and instability as the most common causes for revision [3,37], whereas other authors' results have begun to challenge this notion [38]. Within the MARCQI population, the causes of revision may demonstrate a shifting paradigm. Within 6 months, fracture represented the leading cause of revision (41.8%), followed by dislocation (25.7%) and then infection (12.96%). This trend was true when the data were stratified based on gender and age. All subgroups had fracture as the leading cause of revision within 6 months. Early femur fracture was most pronounced in females more than the age of 75 years, with periprosthetic fracture as the cause for revision in 60.3% of cases (<6 months). Although not quite as pronounced as elderly women, fracture also represented the most common cause for revision in males >75 years at 6 months and remained in the top 2 causes across all time points. Osteopenia and osteoporosis are prevalent in this elderly population [39], suggesting bone quality, bone stock, and perhaps bone morphology contributed meaningfully to the finding. Although the younger age groups also had a high prevalence of early periprosthetic femur fracture, the risk appeared to taper off after 6 months and femur fracture failed to appear in the top 3 causes of revision in any of those groups after 6 months. This again suggests that bone quality contributed to the etiology of revision. In short, periprosthetic

femur fracture is a substantial risk for early THA revision for all patients in the early postoperative period regardless of age or gender. This risk factor declines over time, especially for younger patients. Results from this study suggest that patients cannot be treated with a one-size-fits-all strategy. Many of these early failures are likely preventable and may stem from the decisions that surgeons make. Beyond surgical considerations, surgeons need to consider comorbidities and social factors that may place the patient at an increased risk for early periprosthetic fracture.

Studies in the past, including those from other large databases, have identified aseptic loosening as one of the most common reason for THA revision [3,37,40]. As time progressed, the risk of aseptic loosening as a cause of revision increased in the MARCQI population as a whole. At more than 5 years after index procedure, aseptic loosening became the most prevalent cause for revision in all age/gender-stratified groups. This was especially prominent in the younger subset of the MARCQI population (males and females aged <65 years), for whom the difference between the top causes was significant. Although studies in the past have pointed to monoblock metal-on-metal components as a potential cause of aseptic loosening [37], the findings from the MARCQI population suggest that aseptic loosening remains a problem with more modern hip arthroplasty designs, especially in younger patients.

Large registries can be used to synthesize high volume data over many hospital systems and identify treatment trends and complications which would have been impossible in the past. They have been shown to help improve implant quality and patient outcomes [40,41]. As registries mature and the data analysis becomes more refined, they should be ever-more useful in driving quality improvements in patient care [23]. This study used a state-wide quality improvement total joint registry with a large volume of patients and multiple institutions in the state of Michigan. The relatively large sample size (n = 1,433) provided a clear benefit of the study and the results represented should have generalizability and should translate well to other parts of the nation. This study carries limitations, many of which are inherent to all registry studies. The data are consolidated from a variety of surgeons and institutions, which introduces heterogeneity in implants, surgical technique, and level of expertise, among other factors. Because the data are limited to the state of Michigan, it may have regional biases, including industry affiliations and surgeon training. In addition, our data does not include patient-reported outcome measures, which are relevant to the success of THA, even if a revision surgery is not pursued. Finally, our data does not include full 5-year follow-up data for every queried patient, which leaves open the possibility that more revisions may occur in 1-5 year postoperative period than reported.

This study helps to elucidate meaningful differences in the causes for revision based on age and gender. Periprosthetic fracture is an emerging and consequential risk, particularly in patients aged >75 years. By considering each patient's unique set of risk factors, the arthroplasty surgeon is better equipped to mitigate these risks. We suggest that patients be stratified by age and gender during preoperative planning. Further work will attempt to establish differences in revision rates based on implant geometry and a surgical technique to further aid in surgeon decision making. We anticipate that a treatment algorithm based on patient specific variables can be established to guide surgeons to make the safest and highest quality arthroplasty decisions for their patients.

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References

[1] Capon-Garcia D, Lopez-Pardo A, Alves-Perez M. Causes for revision surgery in total hip replacement. A retrospective epidemiological analysis. Revista Española de Cirugía Ortopédicay Traumatología (English Edition) 2016;60:160–6.
[2] Bozic KJ, Kamath AF, Ong K, Lau E, Kurtz S, Chan V, et al. Comparative epidemiology of revision arthroplasty: failed THA poses greater clinical and economic burdens than failed TKA. Clin Orthop Relat Res 2015;473:2131–8.
[3] Dobzyniak M, Fehring TK, Odum S. Early failure in total hip arthroplasty. Clin Orthop Relat Res 2006;447:76–8.
[4] Gwam CU, Mistry JB, Mohamed NS, Thomas M, Bigart KC, Mont MA, et al. Current epidemiology of revision total hip arthroplasty in the United States: national inpatient sample 2009 to 2013. J Arthroplasty 2017;32:2088–92.
[5] Sadoghi P, Liebensteiner M, Agreiter M, Leithner A, Böhler N, Labek G. Revision surgery after total joint arthroplasty: a complication-based analysis using worldwide arthroplasty registers. J Arthroplasty 2013;28:1329–32.
[6] Burke NG, Gibbons JP, Cassar-Gheiti AJ, Walsh FM, Cashman JP. Total hip replacement-the cause of failure in patients under 50 years old? Ir J Med Sci 2019;188:879–83.
[7] Delaunay C, Hamadouche M, Girard J, Duhamel A. What are the causes for failures of primary hip arthroplasties in France? Clin Orthop Relat Res 2013;471:3863–9.
[8] Kahlenberg CA, Swarup I, Krell EC, Heinz N, Figgie MP. Causes of revision in young patients undergoing total hip arthroplasty. J Arthroplasty 2019;34:1435–40.
[9] Ramavath A, Lamb JN, Palan J, Pandit HG, Jain S. Postoperative periprosthetic femoral fracture around total hip replacements: current concepts and clinical outcomes. EFORT Open Rev 2020;5:558–67.
[10] Abdel MP, Watts CD, Houdek MT, Lewallen DG, Berry DJ. Epidemiology of periprosthetic fracture of the femur in 32,644 primary total hip arthroplasties: a 40-year experience. Bone Jt J 2016;98-b:461–7.
[11] Iamthanaporn K, Chareancholvanich K, Pornrattanamaneewong C. Revision primary total hip replacement: causes and risk factors. J Med Assoc Thai 2015;98:93.
[12] Jafari SM, Coyle C, Mortazavi SJ, Sharkey PF, Parvizi J. Revision hip arthroplasty: infection is the most common cause of failure. Clin Orthop Relat Res 2010;468:2046–51.
[13] Katz JN, Wright EA, Wright J, Malchau H, Mahomed NN, Stedman M, et al. Twelve-year risk of revision after primary total hip replacement in the US Medicare population. J Bone Jt Surg Am 2012;94:1825.
[14] Prokopetz JJ, Losina E, Bliss RL, Wright J, Baron JA, Katz JN. Risk factors for revision of primary total hip arthroplasty: a systematic review. BMC Musculoskelet Disord 2012;13:251.
[15] Angerame MR, Fehring TK, Masonis JL, Mason JB, Odum SM, Springer BD. Early failure of primary total hip arthroplasty: is surgical approach a risk factor? J Arthroplasty 2018;33:1780–5.
[16] Hooper G, Rothwell A, Stringer M, Frampton C. Revision following cemented and uncemented primary total hip replacement: a seven-year analysis from the New Zealand Joint Registry. J Bone Joint Surg Br 2009;91:451–8.
[17] Kenney C, Dick S, Lea J, Liu J, Ebraheim NA. A systematic review of the causes of failure of revision total hip arthroplasty. J Orthop 2019;16:393–5.
[18] Kowalik TD, DeHart M, Gehling H, Gehling P, Schabel K, Duwelius P, et al. The epidemiology of primary and revision total hip arthroplasty in teaching and nonteaching hospitals in the United States. J Am Acad Orthop Surg 2016;24:393–8.
[19] Sueyoshi T, Meding JB, Davis KE, Lackey WG, Malinzak RA, Ritter MA. Clinical predictors for possible failure after total hip arthroplasty. Hip Int 2016;26:531–6.
[20] Gonzalez Della Valle A, Odum SM, De A, Barrington JW, Huddleston JI, Illgen RL, et al. The effect of femoral fixation on revision and mortality following elective total hip arthroplasty in patients over the age of 65 years. An analysis of the American Joint Replacement Registry. J Arthroplasty 2022.
[21] Varnum C, Pedersen AB, Rolfson O, Rogmark C, Furnes O, Hallan G, et al. Impact of hip arthroplasty registers on orthopaedic practice and perspectives for the future. EFORT open Rev 2019;4:368–76.
[22] Springer BD, Cahue S, Etkin CD, Lewallen DG, McGrory BJ. Infection burden in total hip and knee arthroplasties: an international registry-based perspective. Arthroplast Today 2017;3:137–40.
[23] Pugely AJ, Martin CT, Harwood J, Ong KL, Bozic KJ, Callaghan JJ. Database and registry research in orthopaedic surgery: part I: claims-based data. JBJS 2015;97:1278–87.
[24] Pivec R, Johnson AJ, Mears SC, Mont MA. Hip arthroplasty. Lancet 2012;380:1768–77.
[25] Bourne RB, Maloney WJ, Wright JG. An AOA critical issue. The outcome of the outcomes movement. J Bone Jt Surg Am 2004;86:633–40.
[26] Tanzer M, Graves SE, Peng A, Shimmin AJ. Is cemented or Cementless femoral stem fixation more durable in patients older than 75 Years of age? a comparison of the best-performing stems. Clin Orthop Relat Res 2018;476:1428–37.
[27] Hughes REHBR, Zheng H, Kabara J, Cowen M, Igrisan R, Richmond A. Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI) Report: 2012-2016. Ann Arbor: University of Michigan; 2017.
[28] Hughes RHB, Cowen M, Igrisan R, Singal B, Share D. Michigan arthroplasty registry collaborative quality initiative (MARCQI) as a model for regional registries in the United States. Orthop Res Rev 2015;7:47–56.

[29] Bozic KJ, Ong K, Kurtz S, Lau E, Vail TP, Rubash H, et al. Short-term risk of revision THA in the medicare population has not improved with time. Clin Orthop Relat Res 2016;474:156–63.
[30] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. JBJS 2007;89:780–5.
[31] Dy CJ, Bozic KJ, Pan TJ, Wright TM, Padgett DE, Lyman S. Risk factors for early revision after total hip arthroplasty. Arthritis Care Res (Hoboken) 2014;66:907–15.
[32] Kurtz S, Mowat F, Ong K, Chan N, Lau E, Halpern M. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. JBJS 2005;87:1487–97.
[33] Ong KL, Mowat FS, Chan N, Lau E, Halpern MT, Kurtz SM. Economic burden of revision hip and knee arthroplasty in medicare enrollees. Clin Orthop Relat Res 2006;446:22–8.
[34] Lau RL, Gandhi R, Mahomed S, Mahomed N. Patient satisfaction after total knee and hip arthroplasty. Clin Geriatr Med 2012;28:349–65.
[35] Wolford ML, Palso K, Bercovitz A. Hospitalization for total hip replacement among inpatients aged 45 and over: United States, 2000-2010. NCHS Data Brief 2015;186:1–8.
[36] Ayers D, Zheng H, Lemay C, Yang W, Franklin P. One-year total HIP arthroplasty revision rates in the US: incidence and aetiology. In: Paper presented at: Orthopaedic Proceedings. Washington DC: American Society for Bone and Mineral Research; 2018.
[37] Melvin JS, Karthikeyan T, Cope R, Fehring TK. Early failures in total hip arthroplasty—a changing paradigm. J Arthroplasty 2014;29:1285–8.
[38] Goldman AH, Osmon DR, Hanssen AD, Pagnano MW, Berry DJ, Abdel MP. The Lawrence D. Dorr surgical techniques & Technologies Award: aseptic reoperations within one year of primary total hip arthroplasty markedly increase the risk of later periprosthetic joint infection. J Arthroplasty 2020;35:S10–4.
[39] Wright NC, Looker AC, Saag KG, Curtis JR, Delzell ES, Randall S, et al. The recent prevalence of osteoporosis and low bone mass in the United States based on bone mineral density at the femoral neck or lumbar spine. J Bone Miner Res 2014;29:2520–6.
[40] Malchau H, Herberts P, Eisler T, Garellick G, Soderman P. The Swedish total hip replacement register. J Bone Joint Surg Am 2002;84-A(Suppl 2):2–20.
[41] Herberts P, Malchau H. Long-term registration has improved the quality of hip replacement: a review of the Swedish THR Register comparing 160,000 cases. Acta Orthop Scand 2000;71:111–21.