Patient Characteristics Influence Revision Rate of Total Hip Arthroplasty

Peters, Rinne M.; van Steenbergen, Liza N.; Stewart, Roy E.; Stevens, Martin; Rijk, Paul C.; Bulstra, Sjoerd K.; Zijlstra, Wierd P.

Published in:
Journal of Arthroplasty

DOI:
10.1016/j.arth.2019.08.024

Publication date:
2020

The Journal of Arthroplasty 35 (2020) 188–192

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Primary Arthroplasty

Patient Characteristics Influence Revision Rate of Total Hip Arthroplasty: American Society of Anesthesiologists Score and Body Mass Index Were the Strongest Predictors for Short-Term Revision After Primary Total Hip Arthroplasty

Rinne M. Peters, MD [a, b, *], Liza N. van Steenbergen, PhD [c], Roy E. Stewart, PhD [b], Martin Stevens, PhD [b], Paul C. Rijk, MD, PhD [a], Sjoerd K. Bulstra, MD, PhD [b], Wierd P. Zijlstra, MD, PhD [a]

[a] Department of Orthopedic Surgery, Medical Center Leeuwarden, Leeuwarden, The Netherlands
[b] Department of Orthopedic Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
[c] Dutch Arthroplasty Register (Landelijke Registratie Orthopedische Implantaten), 's Hertogenbosch, The Netherlands

ARTICLE INFO

Article history:
Received 12 March 2019
Received in revised form
27 July 2019
Accepted 8 August 2019
Available online 14 August 2019

Keywords:
total hip arthroplasty
case-mix
revision rate
survival
patient characteristics

ABSTRACT

Background: Outcome and survival after primary total hip arthroplasty (THA) can be affected by patient characteristics. We examined the effect of case-mix on revision after primary THA using the Dutch Arthroplasty Register.

Methods: Our cohort included all primary THAs (n = 218,214) performed in patients with osteoarthritis in the Netherlands between 2007 and 2018. Multivariable logistic regression analysis was used to calculate the difference in survivorship in patients with different patient characteristics (age, gender, American Society of Anesthesiologists [ASA] score, body mass index [BMI], Charnley score, smoking, and previous operations to the hip).

Results: Case-mix factors associated with an increased risk for revision 1 year after THA were the following: a high ASA score (II and III-IV) (odds ratio [OR] 1.5, 95% confidence interval [CI] 1.1-2.0 and OR 3.0, 95% CI 1.7-5.3), a higher BMI (30-40 and >40) (OR 1.4, 95% CI 1.2-1.5 and OR 2.0, 95% CI 1.4-1.7), age ≥75 years (OR 1.5, 95% CI 1.1-2.0), and male gender (OR 1.3, 95% CI 1.2-1.4). A similar model for 3-year revision showed comparable results. High BMI (OR 1.9, 95% CI 1.3-2.9), a previous hip operation (OR 1.8, 95% CI 1.3-2.5), ASA III-IV (OR 1.2, 95% CI 1-1.6), and Charnley score C (OR 1.5, 95% CI 1.1-2.2) were associated with increased risk for revision. Main reasons for revision in obese and ASA II-IV patients were infection, dislocation, and periprosthetic fracture. Patients with femoral neck fracture and late post-traumatic pathology were more likely to be revised within 3 years, compared to osteoarthritis patients (OR 1.5, 95% CI 1.3-1.7 and OR 1.5, 95% CI 1.2-1.7).

Conclusion: The short-term risk for revision after primary THA is influenced by case-mix factors. ASA score and BMI (especially >40) were the strongest predictors for 1-year revision after primary THA. After 3 years, BMI and previous hip surgery were independent risk factors for revision. This will help surgeons to identify and counsel high-risk patients and take appropriate preventive measures.

Sources of Funding: R.M.P. and W.P.Z. received a grant (VRF2017-001) from the Van Rens Foundation, which was initiated by the Dutch Orthopedic Society (NOV), in order to perform this study.

Disclosure: None of the authors have any financial or personal relationships with other people or organizations that could potentially and inappropriately influence (bias) this work and its conclusions.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2019.08.024.

* Reprint requests: Rinne M. Peters, MD, Department of Orthopaedic Surgery, Medical Center Leeuwarden, Henri Dunantweg 2, 8901 BR, Leeuwarden, The Netherlands.

https://doi.org/10.1016/j.arth.2019.08.024
0883-5403/

National arthroplasty registry data can be used to evaluate provider and device performance in orthopedic surgery. Both surgical outcome variables (eg, survival) and patient-reported outcome measures may be derived from these registries, in combination with patient characteristics and surgical factors. Registries allow identification of suboptimal performance or inequalities in healthcare and subsequently drive quality improvement [1,2]. When comparing healthcare outcomes, adequate risk adjustment for factors unrelated to the provider or device is warranted [3].

Patient characteristics (case-mix) are known to influence postoperative outcomes, and hence can influence cost as well. Case-mix is defined as the variation in the population, relating to factors such as age, gender, American Society of Anesthesiologists (ASA) physical status, Charnley score, diagnosis, previous operations to the affected joint, smoking status, and body mass index (BMI) [5].

It is important to know preoperatively which patients are at risk for revision surgery. At present, tools are scarce to adequately identify these high-risk patients. The aim of our study is to identify high-risk patients, by determining the effect of case-mix on revision rates after primary total hip arthroplasty (THA) using the data in the Dutch Arthroplasty Register (LROI).

Materials and Methods

Dutch Arthroplasty Registry

In 2007, the LROI was started by the Dutch Orthopedic Society. The LROI is a national data cohort with coverage of all hospitals performing hip replacement surgery in the Netherlands. The level of completeness is more than 95% for primary THAs [4]. LROI contains demographic information (eg, age, gender, ASA score, diagnosis, previous surgery to the affected joint), surgical variables (eg, surgical approach, fixation technique), prosthesis characteristics (eg, femoral head size and bearing type), and survival of the prosthesis. Smoking behaviour, orthopedic vitality (ie, Charnley score), and BMI have been added in 2014. The LROI is linked to Vektis, the Dutch national insurance database for healthcare data [5].

All primary hip arthroplasties performed in the Netherlands between 2007 and 2018 were incorporated in the dataset (n = 259,849). Patients with bilateral prosthesis were included. Metal-on-metal THAs were excluded (n = 6635), because these are known to result in higher revision rates [6–8]. Hereafter, the cohort contained 253,214 procedures. Since preoperative diagnosis may impact revision rates differently, only patients with osteoarthritis (OA) were included in our main analysis (n = 218,214). Baseline characteristics and operation details were categorized (Fig. 1). This was similar to previous studies using LROI data [4,8,9,14]. Smoking status, BMI, and Charnley score were registered since 2014 in the LROI. The median length of follow-up was 4.9 years, with a maximum of 12.0 years. The minimum length of follow-up was 1.0 year.

Statistics

Survival (with 95% confidence interval [CI]) was defined as time from primary THA to first revision procedure for any reason, death of the patient, or end of follow-up (January 1, 2019). The cumulative incidence of revision was calculated using competing risk analysis, where death was considered to be a competing risk [10–14]. Crude cumulative revision percentages within 1, 5, and 9 years were determined. In order to test for differences in revision rates between case-mix subgroups, multivariable logistic regression analyses were performed, based on 1-year and 3-year revision rate, while adjusting for confounders. The following confounding factors were entered into the model: age, gender, ASA score, and previous operation to the affected hip. Because smoking status, Charnley score, and BMI were registered since 2014, a subset of procedures performed in 2014-2017 with a follow-up of 1 year was used to calculate the odds ratios (ORs) of revision within 1 year. For the 3-year revision rate procedures performed in 2014-2015 were selected to assure at least 3-year follow-up. Interaction was tested between age and respectively ASA, smoking, and BMI. Goodness-of-fit was tested using Nagelkerke R^2 and the Hosmer and Lemeshow test (HL test) to examine how well the model fitted the data.

Furthermore, revision rates according to the reason for revision were provided. Group comparisons according to case-mix (dichotomous) were performed using chi-squared tests. Categorical variables were made binary to simplify interpretation: age <60 or ≥60 years, ASA I-II vs ASA III-IV, Charnley A, B1, or B2 vs C, and BMI <30 vs BMI ≥30. *P*-values below .05 were considered statistically significant. All analyses were performed using SPSS version 23.0.

Ethical Approval

Ethical approval for this study was obtained by the Medical Ethics Committee of University Medical Center Groningen (no. 154 METc2017/388).

Results

Overall Crude Cumulative Incidence of Revision

In total, 218,214 THAs were included (Table 1 and Appendix Table 4), of which 6552 were revised. The overall crude 1, 3, 5, and 9-year revision rates were respectively 1.5 (95% CI 1.5-1.6), 2.5 (2.4-2.5), 3.0 (3.0-3.1), and 4.0 (3.9-4.1) (Fig. 2, Appendix Table 1).

Overall Adjusted Revision Rates According to Case-Mix

Multivariable logistic regression analyses demonstrated that patients with OA were more likely to have a revision within 1 year after primary THA when they had a high ASA score (II and III-IV) (respectively OR 1.51 and 3.00) or high BMI (30-40 and ≥40) (respectively OR 1.35 and 1.96). In addition, patients aged 75 years

Demographic data:
- age (<60, 60–74, and ≥75 years), gender (male/female), ASA-score (I, II, III-IV), diagnosis, previous operation to the affected hip (yes/no), smoking status (yes/no), BMI (<18.5, 18.5-25, 25-30, 30-40, and ≥40) and Charnley score (A, B1, B2, and C)

Surgical variables:
- surgical approach (direct anterior, anterolateral, straight lateral, posterolateral, other), fixation technique (cementless, cemented, reversed hybrid, hybrid)

Prosthesis characteristics:
- femoral head size (22-28 mm, 32 mm, 36 mm, ≥ 38 mm), bearing type (metal on PE, ceramic on PE, ceramic on ceramic, oxidized zirconium on PE)

Fig. 1. Dutch Arthroplasty Register data: variable overview.

Table 1
Patient Characteristics of All Patients With Osteoarthritis Who Received a Primary THA (n = 218,214) in the Period 2007-2018 in the Netherlands.

Total Hip Arthroplasty (n = 218,214)	
	n (%)
Age	
<60	30,937 (14.2)
60-74	113,878 (52.2)
≥75	73,399 (33.6)
Gender	
Male	71,447 (32.8)
Female	146,489 (67.2)
ASA score	
I	47,114 (22.3)
II	136,082 (64.3)
III-IV	28,269 (13.4)
Previous operation	
Yes	4495 (2.2)
No	203,742 (97.8)
Period	
2007-2010	53,458 (24.5)
2011-2014	88,132 (40.4)
2015-2017	76,624 (35.1)
Smoking	
Yes	11,248 (5.2)
No	90,149 (41.3)
Not registered; before 2014	116,817 (53.5)
Charnley score	
A	44,080 (20.4)
B1	30,267 (14.1)
B2	22,010 (10.2)
C	2288 (1.1)
Not registered; before 2014	117,477 (54.2)
BMI (kg/m^2)	
≤18.5	649 (0.3)
>18.5-25	33,998 (15.6)
>25-30	46,507 (21.3)
>30-40	25,453 (11.7)
>40	1336 (0.6)
Not registered; before 2014	108,011 (49.5)

Numbers do not add up to total due to unknown or missing values.
THA, total hip arthroplasty; ASA, American Society of Anesthesiologists; BMI, body mass index.

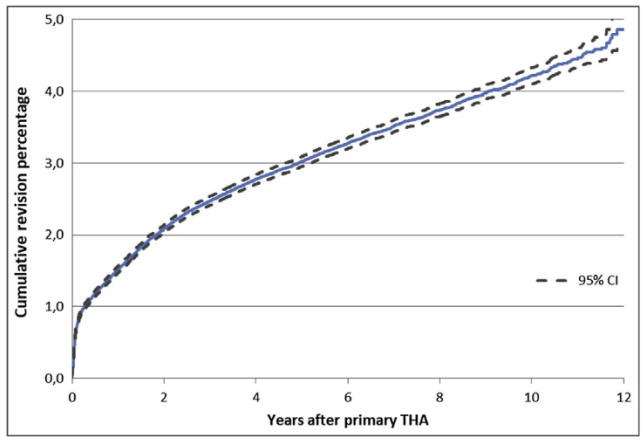

Fig. 2. Overall crude cumulative incidence of revision (non-case-mix corrected) for primary THA in patients with OA between 2007-2018 (n = 218,214).

or older (OR 1.50) or male (OR 1.29) were more likely to have a revision within 1 year (Table 2). A similar model for 3-year revision showed comparable results. However, age was no longer associated with an increased risk of 3-year revision, whereas a previous operation to the affected hip joint and a Charnley score C were independent risk factors for enhanced 3-year revision rates. The interaction term between age and ASA was a statistically significant factor for 1-year revision rate, while this was no longer significant in the model for 3-year revision rate. The goodness-of-fit tests showed a rather good fit of the 1-year and 3-year revision models (1-year revision model: HL test $P = .16$, Nagelkerke R^2 0.010; 3-year revision model: HL test $P = .47$, Nagelkerke R^2 0.009).

A subanalysis focusing on OA patients vs patients with other diagnoses (fracture, osteonecrosis, late post-traumatic changes, dysplasia, and other) demonstrated that patients operated for a fracture or for late post-traumatic pathology had a significantly higher risk for revision within 3 years compared to patients with OA (respectively OR 1.5, 95% CI 1.3-1.7 for fracture and OR 1.5, 95% CI 1.2-1.7 for late post-traumatic) (data not shown). Furthermore, it was demonstrated that the influence of case-mix variables of revision rate varied among patients with different preoperative diagnoses. Stratified analyses per diagnosis showed that patients with a hip fracture were more likely to undergo a revision procedure if they had a high ASA score (OR 2.7, 95% CI 1.1-6.9) or were male (OR 1.9, 95% CI 1.1-3.2) (data not shown). In patients with osteonecrosis, only smoking was associated with an increased 3-year revision rate (OR 2.0, 95% CI 1.0-3.9). In patients with late post-traumatic changes and dysplasia, a BMI above 40 (respectively OR 44.5, 95% CI 2.3-858.5 and OR 29.7, 95% CI 3.5-253.9) was associated with an increased risk for revision (data not shown).

Reasons for Revision

The reason for revision varied according to the length of the follow-up. After 1 year the most frequently registered reason for revision was dislocation (33%), followed by infection (23%) and periprosthetic fracture (18%) (data not shown). After 5 years, THAs were most commonly revised due to dislocation (32%) and loosening of the femoral (22%) or acetabular (14%) component. At 9-year follow-up, recurrent dislocation continued to be the most frequently registered reason for revision of primary THA in the Netherlands, followed by loosening of the femur (24%) or acetabulum (16%).

Revisions for infection were more common in patients with an ASA score III-IV, a BMI over 30, aged under 60, and females (Appendix Tables 2 and 3). Revision due to a periprosthetic fracture was more frequently registered in patients with ASA score III-IV, Charnley score C, and in elderly and male patients. For dislocation, case-mix did not matter. Loosening of the femoral or acetabular component and liner wear as reason for revision was more common in the elderly. Loosening of the femoral component was observed more in patients with high BMI.

Discussion

In this arthroplasty registry study, our primary goal was to identify high risk patients, by determining the effect of case-mix on short-term revision rates after primary THA in the Netherlands. We found higher revision rates 1 year after primary THA in patients with morbid obesity (BMI >40), high ASA scores (III-IV), patients aged 75 or older, or male patients. After 3 years, a high BMI, surgical history to the hip, Charnley score C, male gender, and a high ASA score were independently associated with an increased risk for revision. Main reasons for revision in obese and ASA II-IV patients were infection and periprosthetic fracture. Furthermore, we found that patients with a femoral neck fracture and patients with late post-traumatic changes were more likely to undergo a revision, compared to OA patients.

Adequate risk adjustment is required in order to enable fair comparisons between hospitals and providers [3]. Schilling et al

Table 2
Multivariable Logistic Regression Analysis of 1-y and 3 y Revision Percentages After Primary THA in the Netherlands, in Patients With Osteoarthritis.

Total Hip Arthroplasty (n = 100,737)[a] Revised Within 1 y: 1737 (1.7%) 2014-2017		
1 y	Odds Ratio (95% CI)	*P*-Value
Age (y)		
<60	0.72 (0.55-0.96)	.02
60-74	1.0	
≥75	1.50 (1.11-2.03)	.01
Gender		
Male	1.29 (1.16-1.43)	<.001
Female	1.0	
ASA score		
I	1.0	
II	1.51 (1.13-2.00)	.01
III-IV	3.00 (1.69-5.33)	<.001
Previous operation		
Yes	1.26 (0.91-1.75)	.17
No	1.0	
Smoking		
Yes	1.13 (0.97-1.32)	.11
No	1.0	
BMI (kg/m^2)		
≤18.5	1.33 (0.74-2.37)	.34
>18.5-25	0.86 (0.76-0.98)	.02
>25-30	1.0	
>30-40	1.35 (1.20-1.52)	<.001
>40	1.96 (1.42-2.72)	<.001
Charnley score		
A	1.0	
B1	0.98 (0.87-1.11)	.78
B2	1.12 (0.99-1.27)	.08
C	1.29 (0.97-1.72)	.08
Interaction term		
ASA × age	0.85 (0.75-0.97)	.01
Total Hip Arthroplasty (n = 48,918)[a] Revised Within 3 y: 1227 (2.5%) 2014-2015		
3 y	Odds Ratio (95% CI)	*P*-Value
Age (y)		
<60	1.13 (0.95-1.34)	.17
60-74	1.0	
≥75	1.02 (0.88-1.17)	.82
Gender		
Male	1.25 (1.10-1.42)	.001
Female	1.0	
ASA score		
I	1.0	
II	1.06 (0.90-1.25)	.50
III-IV	1.24 (1.00-1.55)	.05
Previous operation		
Yes	1.77 (1.27-2.47)	.001
No	1.0	
Smoking		
Yes	1.12 (0.93-1.34)	.23
No	1.0	
BMI (kg/m^2)		
≤18.5	1.73 (0.94-3.20)	.08
>18.5-25	0.76 (0.65-0.88)	<.001
>25-30	1.0	
>30-40	1.15 (0.99-1.33)	.07
>40	1.91 (1.27-2.86)	.002
Charnley score		
A	1.0	
B1	0.97 (0.84-1.12)	.67
B2	1.06 (0.91-1.24)	.47
C	1.51 (1.06-2.15)	.02

THA, total hip arthroplasty; CI, confidence interval; ASA, American Society of Anesthesiologists; BMI, body mass index.
[a] Adjusted for age at surgery, gender, ASA score, diagnosis, previous operation, smoking status, Charnley score and BMI.

[15] developed a series of risk-adjustment models specific to 30-day morbidity and mortality following hip fracture repair, THA, and total knee arthroplasty procedures by using prospectively collected data in the United States. According to the results, regression models that account for differences in demographics, ASA classification, comorbidities, laboratory values, and vital signs can be used to make fair comparisons of outcome measures intended to characterize quality of care per provider. Similar case-mix adjustments were applied in the 12th annual report of the National Joint Registry of England, Wales, Northern Ireland, and the Isle of Man. When comparing the observed numbers of revision surgeries of hip replacement for each hospital in the period 2003-2014 to the numbers expected, the data were corrected for age, gender, and reason for primary surgery [16]. In the Netherlands, similar adjustments for case-mix factors were used for the annual quality performance indicator "1-year revision rate" defined by the Care Institute Netherlands, health insurance companies, the Netherlands Orthopedic Association, and the Patient Federation Netherlands. It is however debated, which specific case-mix factors should be used for these kinds of comparisons. The growing number of case-mix factors that have been added to the Dutch Arthroplasty Registry, especially since 2014, enabled us to perform new calculations with a broad set of case-mix variables. Based on the results of this study, registry outcomes of THA should be adjusted for age, gender, ASA score, BMI, diagnosis, and previous operations, in order to make fare comparisons.

Patient Characteristics

THA is consistently identified as a successful treatment for end-stage OA of the hip joint with high survival rates and a significant improvement in quality of life after the procedure. Given the success of the surgery, it has been suggested that the focus of research should perhaps shift toward patient selection for these procedures to optimize outcomes and health resources [17]. Multiple factors are known to influence the risk for revision after joint replacement surgery. Most patient factors cannot be modified, although smoking status and BMI can be modified.

A high ASA score and severe obesity were the strongest predictors for short-term revision after a primary THA in patients with OA. This is similar to previous studies. Wagner et al [17] analyzed 21,361 consecutive THAs from their institutional database and demonstrated that reoperation and implant revision were strongly associated with BMI. Increasing BMI was significantly associated with increased rates of early hip dislocation, wound infection, and deep periprosthetic infection (OR of 1.09 per unit of BMI >25) [17]. We also found higher rates of periprosthetic infection revisions in obese patients.

Diagnosis

Our data demonstrated that the preoperative diagnosis and indication for THA influenced short-term revision rates. Compared to OA patients, those with an acute fracture or late post-traumatic hip pathology showed increased short-term revision rates. In general, high BMI and high ASA scores increased the risks of short-term revision, but the influence of case-mix variables on revision rate varied with different preoperative diagnoses. For instance, smoking was only associated with a higher risk for revision in patients with osteonecrosis.

Reasons for Revision

We demonstrated that the reason for revision differed among patients with differences in case-mix. Main reasons for revision were dislocation, infection, and periprosthetic infection. Infection revisions were more common in obese patients and in patients

with an ASA score III-IV; smoking did not matter. Periprosthetic fracture revisions were performed more frequently in ASA III-IV, Charnley C, and elderly patients. Dislocation revisions were common, but case-mix did not seem to matter based on our data. In literature however, advanced age, previous surgery, ASA III-IV, and BMI >30 have been associated with increased risk of dislocation [19].

Based on the results of this study, patient characteristics can be used to help surgeons counsel patients and give a patient-tailored advice, in order to decrease the risk for short-term revision after THA. For example, the diagnosis is a non-modifiable risk factor which could be taken into account during preoperative planning. In order to reduce the risk for dislocation in patients with an acute femoral neck fracture and late post-traumatic pathology, the use of a larger (eg, 36 vs 32 mm) femoral head component or a change in surgical approach could be considered, to reduce the risk for revision due to recurrent dislocation [8]. For obese patients, strategies to minimize infection should be optimized, for instance, the dose of perioperative cefazolin should be adjusted to 3 g instead of 2 g in case of BMI >40 or perhaps >35 [18]. Furthermore, for ASA III-IV patients, one might consider a cemented prosthesis, in order to reduce the risk of periprosthetic fracture [8].

Limitations

Arthroplasty registry studies have the advantage of using national population-based routinely collected data. However, rather limited patient characteristics have been collected since the start of the registry in 2007. BMI, Charnley score, and smoking status were only added to the registry in 2014, thus limiting the follow-up time. The HL tests proved that our model fitted the dataset well, but the predictive ability of our model, as shown by explained variance (R^2), was low, perhaps due to this limited set of patient characteristics. Furthermore, arthroplasty registry data are observational data, therefore residual confounding can remain and causality cannot be distracted from our data.

Conclusion

The short-term risk for revision after primary THA is influenced by case-mix factors. ASA score and BMI (especially >40) were the strongest predictors for 1-year revision after primary THA. After 3 years, BMI and previous hip surgery were independent risk factors for revision. Main reasons for revision in obese and ASA II-IV patients were infection, dislocation, and periprosthetic fracture. This will help surgeons to identify and counsel high-risk patients and take appropriate preventive measures.

Acknowledgments

The authors would like to thank the Van Rens Foundation for funding this study.

References

[1] Lekander I, Willers C, Ekstrand E, von Euler M, Fagervall-Yttling B, Henricson L, Kostulas K, Lilja M, Sunnerhagen KS, Teichert J, Pessah-Rasmussen H, et al. Hospital comparison of stroke care in Sweden: a register based study. BMJ Open 2017;7:e015244. https://doi.org/10.1136/bmjopen-2016-015244.
[2] Burns EM, Pettengell C, Athanasiou T, Darzi A. Understanding the strengths and weaknesses of public reporting of surgeon-specific outcome data. Health Aff (Millwood) 2016;35:415–21. https://doi.org/10.1377/hlthaff.2015.0788.
[3] SooHoo NF, Li Z, Chan V, Chenok K, Bozic KJ. The importance of risk adjustment in reporting total joint arthroplasty outcomes. J Arthroplasty 2016;31:590–5. https://doi.org/10.1016/j.arth.2015.09.041.
[4] Steenbergen van LN, Denissen GA, Spooren A, van Rooden SM, Oosterhout van FJ, Morrenhof JW, et al. More than 95% completeness of reported procedures in the population-based Dutch Arthroplasty Register. Acta Orthop 2015;86:498–505. https://doi.org/10.3109/17453674.2015.1028307.
[5] Vektis. www.Vektis.nl [accessed 01.01.17].
[6] Drummond J, Tran P, Fary C. Metal-on-metal hip arthroplasty: a review of adverse reactions and patient management. J Funct Biomater 2015;6:486–99. https://doi.org/10.3390/jfb6030486.
[7] Nederlandse Orthopaedisch Vereniging. Advies Metaal-op-Metaal Heupprothesen per 1 augustus. https://www.orthopeden.org/downloads/80/advies-mom-per-01-08-2015.pdf; 2015. [accessed 02.07.2019].
[8] Zijlstra WP, De Hartog B, Van Steenbergen LN, Scheurs BW, Nelissen RGHH. Effect of femoral head size and surgical approach on risk of revision for dislocation after total hip arthroplasty. Acta Orthop 2017;88:392–401. https://doi.org/10.1080/17453674.2017.1317515.
[9] Peters RM, van Beers LWAH, Steenbergen van LN, Wolkenfelt J, Ettema HB, Have ten BLEF, et al. Similar superior patient reported outcome measures (PROMs) for anterior and posterolateral approach after total hip arthroplasty in the Netherlands. J Arthroplasty 2018;33:1786–93. https://doi.org/10.1016/j.arth.2018.01.055.
[10] Lacny S, Wilson T, Clement F, Roberts DJ, Faris PD, Ghali WA, et al. Kaplan-Meier survival analysis overestimates the risk of revision arthroplasty: a meta analysis. Clin Orthop Relat Res 2015;473:3431–42. https://doi.org/10.1007/s11999-015-4291-0.
[11] Wongworawat MD, Dobbs MB, Gebhardt MC, Gioe TJ, Leopold SS, Manner PA, et al. Editorial: estimating survivorship in the face of competing risks. Clin Orthop Relat Res 2015;473:1173–6. https://doi.org/10.1007/s11999-015-4182-4.
[12] Putter H, Fiocco M, Geskus RB. Tutorial in biostatistics: competing risks and multi-state models. Stat Med 2007;26:2389–430. https://doi.org/10.1002/sim.2712.
[13] Keurentjes JC, Fiocco M, Schreurs BW, Pijls BG, Nouta KA, Nelissen RGHH. Revision surgery is overestimated in hip replacement. Bone Joint Res 2012;1:258–62. https://doi.org/10.1302/2046-3758.110.2000104.
[14] Peters RM, Steenbergen van LN, Stevens M, Rijk PC, Bulstra SK, Zijlstra WP. The effect of bearing type on the outcome of total hip arthroplasty. Analyses of 209,912 primary total hip arthroplasty registered in the Dutch Arthroplasty Register. Acta Orthop 2018 Apr;89:163–9. https://doi.org/10.1080/17453674.2017.1405669.
[15] Schilling PL, Bozic KJ. Development and validation of perioperative risk-adjustment models for hip fracture repair, total hip arthroplasty, and total knee arthroplasty. J Bone Joint Surg Am 2016;98:e2. https://doi.org/10.2106/JBJS.N.01330.
[16] National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. 12th Annual Report, http://www.njrcentre.org.uk/njrcentre/Portals/0/Documents/England/Reports/12th%20annual%20report/NJR%20Online%20Annual%20Report%202015.pdf; 2015. [accessed 02.07.2019].
[17] Wagner ER, Kamath AF, Fruth KM, Harmsen WS, Berry DJ. Effect of body mass index on complications and reoperations after total hip arthroplasty. J Bone Joint Surg Am 2016;98:169–79. https://doi.org/10.2106/JBJS.O.00430.
[18] Löwik CAM, Zijlstra WP, Knobben BAS, Ploegmakers JJW, Dijkstra B, de Vries AJ, et al., Northern Infection Network Joint Arthroplasty (NINJA). Obese patients have higher rates of polymicrobial and Gram-negative early periprosthetic joint infections of the hip than non-obese patients. PLoS One 2019;14:e0215035. https://doi.org/10.1371/journal.pone.0215035.
[19] Jones CW, De Martino I, D'Apolito R, Nocon AA, Sculco PK, Sculco TP. The use of dual-mobility bearings in patients at high risk of dislocation. Bone Joint J 2019;101-B(1 Suppl. A):41–5. https://doi.org/10.1302/0301-620X.101B1.BJJ-2018-0506.R1.

Appendix

Table s1
Overall Crude Cumulative Incidence of Revision (Non-Case-Mix Corrected) for THA.

Revision for Any Reason	Total Hip Arthroplasty
	Proportion % (95% CI)
1 y	1.4 (1.4-1.5)
3 y	2.4 (2.4-2.5)
5 y	3.0 (2.9-3.1)
9 y	4.2 (4.0-4.4)

THA, total hip arthroplasty; CI, confidence interval.

Table s2
Reasons for Revision in Revised THAs in Patients With Osteoarthritis, Performed Between 2007 and 2018 in the Netherlands According to Age, Gender, and ASA Score.

Revision Within Follow-Up Period	Age <60 n = 30,937, of which 1220 (3.9%) Were Revised	Age ≥60 n = 187,277, of which 5332 (2.8%) Were Revised	Male n = 71,447, of which 2413 (3.4%) Were Revised	Female n = 146,489, of which 4134 (2.8%) Were Revised	ASA I-II n = 183,196, of which 5393 (2.9%) Were Revised	ASA III-IV n = 28,269, of which 887 (3.1%) Were Revised
Infection	199 (0.6)	977 (0.5)[a]	616 (0.4)	558 (0.8)[b]	921 (0.5)	220 (0.8)[b]
Periprosthetic fracture	93 (0.3)	845 (0.5)[b]	692 (0.5)	246 (0.3)[a]	769 (0.4)	143 (0.5)[a]
Dislocation	268 (0.9)	1566 (0.8)	1242 (0.8)	592 (0.8)	1513 (0.8)	258 (0.9)
Loosening of femur	300 (1.0)	1116 (0.6)[b]	767 (0.5)	647 (0.9)[b]	1160 (0.6)	179 (0.6)
Loosening of acetabulum	168 (0.5)	669 (0.4)[b]	593 (0.4)	243 (0.3)[a]	711 (0.4)	87 (0.3)[a]
Cup/liner wear	61 (0.2)	139 (0.1)[b]	145 (0.1)	55 (0.1)	167 (0.1)	14 (0.0)[a]
Periarticular ossification	23 (0.1)	79 (0.0)[a]	53 (0.0)	49 (0.1)[a]	81 (0.0)	10 (0.0)
Girdlestone	37 (0.1)	164 (0.1)	116 (0.1)	85 (0.1)[a]	157 (0.1)	28 (0.1)
Other	258 (0.8)	772 (0.4)[b]	670 (0.5)	360 (0.5)	865 (0.5)	120 (0.4)

Data are represented as n (%). A patient may have more than 1 reason for revision. As such, the total may exceed the actual number of revisions.
THA, total hip arthroplasty; ASA, American Society of Anesthesiologists.
[a] $P < .05$ for dichotomous patient characteristics (eg, age <60 vs age >60).
[b] $P < .0001$ for dichotomous patient characteristics (eg, age <60 vs age >60).

Table s3
Reasons for Revision in Revised THAs in Patients With Osteoarthritis, Performed Between 2007 and 2018 in the Netherlands According to BMI, Charnley Score, and Smoking Status.

Revision Within Follow-Up Period	Charnley A, B1, or B2 n = 96,357, of which 2417 (2.5%) Were Revised	Charnley C n = 2288, of which 79 (3.5%) Were Revised	Smoker n = 10,337, of which 303 (2.9%) Were Revised	Nonsmoker n = 83,459, of which 2079 (2.5%) Were Revised	BMI <30 n = 73,986, of which 1697 (2.3%) Were Revised	BMI ≥30 n = 24,495, of which 799 (3.3%) Were Revised
Infection	701 (0.7)	22 (1.0)	78 (0.8)	627 (0.8)	417 (0.6)	305 (1.2)[a]
Periprosthetic fracture	354 (0.4)	19 (0.8)[a]	49 (0.5)	304 (0.4)	280 (0.4)	96 (0.4)
Dislocation	647 (0.7)	20 (0.9)	84 (0.8)	545 (0.7)	496 (0.7)	177 (0.7)
Loosening of femur	419 (0.4)	12 (0.5)	51 (0.5)	352 (0.4)	298 (0.4)	131 (0.5)[b]
Loosening of acetabulum	222 (0.2)	6 (0.3)	26 (0.3)	184 (0.2)	165 (0.2)	55 (0.2)
Cup/liner wear	43 (0.0)	0 (0.0)	6 (0.1)	34 (0.0)	25 (0.0)	18 (0.1)[b]
Periarticular ossification	25 (0.0)	0 (0.0)	4 (0.0)	21 (0.0)	13 (0.0)	12 (0.0)[b]
Girdlestone	49 (0.1)	1 (0.0)	7 (0.1)	43 (0.1)	31 (0.0)	20 (0.1)[b]
Other	322 (0.3)	13 (0.6)	39 (0.4)	275 (0.3)	228 (0.3)	106 (0.4)[b]

Data are represented as n (%). A patient may have more than 1 reason for revision or reoperation. As such, the total may exceed the actual number of revisions.
THA, total hip arthroplasty; BMI, body mass index.
[a] $P < .0001$ for dichotomous patient characteristics (eg, smoker vs nonsmoker).
[b] $P < .05$ for dichotomous patient characteristics (eg, smoker vs nonsmoker).

Table s4
Procedure Characteristics of All THAs (n = 218,214) Performed in the Period 2007-2018 in the Netherlands.

Total Hip Arthroplasty (n = 218,214)	
	n (%)
Fixation	
Cementless	135,909 (62.8)
Cemented	61,174 (28.3)
Reversed hybrid	8821 (4.1)
Hybrid	10,318 (4.8)
Approach	
Direct anterior	28,028 (13.0)
Anterolateral	15,456 (7.2)
Straight lateral	41,844 (19.4)
Posterolateral	130,003 (60.2)
Other	741 (0.3)
Femoral head size (mm)	
22-28	63,834 (31.2)
32	99,040 (48.3)
36	40,609 (19.8)
≥38	1433 (0.7)
Articulation	
Metal on PE	63,225 (29.0)
Ceramic on PE	108,023 (49.5)
Ceramic on ceramic	16,314 (7.5)
Oxidized zirconium on PE	12,170 (5.6)
Other	18,482 (8.5)

Numbers do not add up to total due to unknown or missing values.
THA, total hip arthroplasty; PE, polyethylene.