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# Multiple Joint Arthroplasty in Hip and Knee Osteoarthritis Patients: A National Longitudinal Cohort Study

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ABSTRACT

*Background:* Many patients suffer from osteoarthritis (OA) in multiple joints, possibly resulting in multiple joint arthroplasties (MJAs). Primarily, we determined the cumulative incidence ($C_{in}$) of MJA in hip and knee joints up to 10 years. Secondly, we calculated the mean time between the first and subsequent joint arthroplasty, and evaluated the different MJA trajectories. Lastly, we compared patient characteristics and outcomes (functionality and pain) after surgery between MJA patients and single hip arthroplasty or knee arthroplasty (HA and KA) patients.

*Methods:* Primary index (first) HA or KA for OA were extracted from the Dutch Arthroplasty Register. The 1, 2, 5, and 10-year $C_{in}$ (including competing risk death) of MJA, mean time intervals, and MJA-trajectories were calculated and stratified for primary index HA or KA. Sex, preoperative age, and body mass index were compared using ordinal logistic regression. Outcomes, measured preoperatively, 3, 6, and 12 months postoperatively (function: Hip Disability or Knee Injury and OA Outcome Score; Pain: Numerical Rating Scale), were compared using linear regression.

*Results:* A total of 140,406 HA-patients and 140,268 KA-patients were included. One, 2, 5, and 10-year $C_{in}$ for a second arthroplasty were respectively 8.9% [95% confidence interval (CI): 8.7 to 9.0], 14.3% [95% CI: 14.1 to 14.5], 24.0% [95% CI: 23.7 to 24.2], and 32.7% [95% CI: 32.2 to 33.1] after index HA, and 9.5% [95% CI: 9.4 to 9.7], 16.0% [95% CI: 15.9 to 16.2], 26.4% [95% CI: 26.1 to 26.6], and 35.8% [95% CI: 35.4 to 36.3] after index KA. The 10-year $C_{in}$ for > 2 arthroplasties were small in both the index HA and KA groups. Time-intervals from first to second, third, and fourth arthroplasty were 26 [95% CI: 26.1 to 26.7], 47 [95% CI: 46.4 to 48.4], and 58 [95% CI: 55.4 to 61.1] months after index HA, and 26 [95% CI: 25.9 to 26.3], 52 [95% CI: 50.8 to 52.7], and 61 [95% CI: 58.3 to 63.4] months after index KA. There were 83% of the second arthroplasties placed in the contralateral cognate joint (ie, knee or hip). Differences in postoperative functionality and pain between MJAs and single HAs and KAs were small.

*Conclusions:* The 10-year $C_{in}$ showed that about one-third of patients received a second arthroplasty after approximately 2 years, with the majority in the contralateral cognate joint. Few patients received > 2 arthroplasties within 10 years. Being a women, having a higher body mass index, and being younger increased the odds of MJA. Postoperative outcomes were slightly negatively affected by MJA.



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Osteoarthritis (OA) often affects multiple joints within an individual [1,2]. As such, a considerable number of OA patients are at risk of multiple joint arthroplasties (MJAs). Hip and knee arthroplasties (KAs) are indicated for end stage OA when patients have severe joint pain and limited mobility and when conservative treatments such as pain medication or physical therapy no longer suffice. Previous studies reported a MJA prevalence of 27% at 5 to 8 years after first joint arthroplasty, while the 10- and 20-year cumulative incidences ($C_{in}$) range between 29 and 45% [3–9], showing that many OA patients receive MJA.

Within MJA patients, the timeframe between arthroplasty procedures may affect the outcome after primary joint arthroplasty [10]. For instance, if a patient receives a second arthroplasty within the first year of the index (ie, first) arthroplasty, it is likely that patient-reported outcomes (PROs) in the first year after surgery reflect the continued symptoms of the second arthroplasty rather than recovery after the first arthroplasty. The literature on the impact of MJA on postoperative outcomes is limited, as the majority of studies reporting outcomes after arthroplasty are performed in patients who have single joint arthroplasty (SJA), include small numbers of patients, or present information on the safety of bilateral joint arthroplasty during one single procedure. Previous studies showed that patients who have MJA or multiple joint pain sites more frequently reported worse pain, greater disability, reduced quality of life, and increased health care utilization prior to surgery [11–17]. Outcomes based on SJA patients provide an overoptimistic impression of the severity of OA, and are likely not directly transferable. Therefore, not including the number of affected joints or the number of arthroplasties performed over time in an individual patient might provide biased results [18]. Additionally, patients who have MJA have to be distinguished from patients who have SJA, since they are likely to belong to different phenotypes of OA.

Thus, it is important to evaluate the possibility and outcomes of additional successive arthroplasties in different joints during the follow-up of the index primary arthroplasty and to identify patient characteristics predictive of MJA. The identification of patients who have increased risks of MJA helps to provide better fitting expectation management and informed decision-making for both the individual patient and orthopaedicsurgeon.

Currently, valid estimates of the yearly incidence, trajectories, and time intervals between index and successive joint arthroplasties are lacking. Additionally, it is unclear whether patient characteristics and PROs differ between patients who have MJA and SJA. Therefore, the primary aim of this study was to determine the 1, 2, 5, and 10-year $C_{in}$ of MJA in hip and knee joints. Secondly, we calculated the mean time between index arthroplasty and subsequent arthroplasties and the frequency of MJA trajectories. Furthermore, we compared patient characteristics and postoperative PROs regarding function and pain between MJA and SJA patients.

## Materials and Methods

The study was approved by the Ethics Committee Leiden|Den Haag|Delft, Germany (G21-024).

### *Data Source*

This population-based cohort study included data on primary hip and KAs from the Dutch Arthroplasty Register (Landelijke Registratie Orthopedische Interventies [LROI]). The LROI contains data on the procedure, prosthesis, and patient characteristics of primary and revision arthroplasties. To ascertain the accurate lifespan of an arthroplasty, the death of a patient is documented in the registry through integration with Vektis (the care information center, collecting and analyzing data on costs and quality of care in the Netherlands). The registry includes arthroplasty patients from 2007 onwards and has a completeness of 99% for primary hip arthroplasties (HAs) and KAs [19].

### *Study Population*

The study population consisted of primary hip or KA patients in the Dutch Arthroplasty Register (LROI) between 2011 and 2020 who had a diagnosis of OA. To correctly identify index (ie, first) joints between 2011 and 2020, the data available in the LROI between 2007 and 2011 were used. If an index joint (either hip and/or knee) was present between 2007 and 2011, patients were excluded. Furthermore, we increased the certainty of identified index joints by first verifying the index joint with the Charnley classification (A, B1, B2, C, n/a) obtained from the LROI and secondly by the record of revision surgery as the first surgery in the LROI. Using these verification methods, we increased the reliability and validity of the estimated $C_{in}$ of MJA.

### *Subpopulations to Investigate Patient Characteristics and Patient-Reported Outcomes*

To allow for sufficient follow-up time to have a MJA (ie, 5 years), while minimizing the likelihood of a previous arthroplasty being missed in the LROI data, we used a subset of the study population to examine differences in patient characteristics and PROs between patients who had MJA and patients who had SJA. In this subpopulation, we included all index arthroplasty joints registered in the LROI in 2015 (Figure 1). Selecting all index arthroplasties performed in 2015, patients had 5 years to 'develop' MJA. This time span was chosen based on previous literature in which time periods between a first and second arthroplasty of the lower extremity were assessed [3,4].

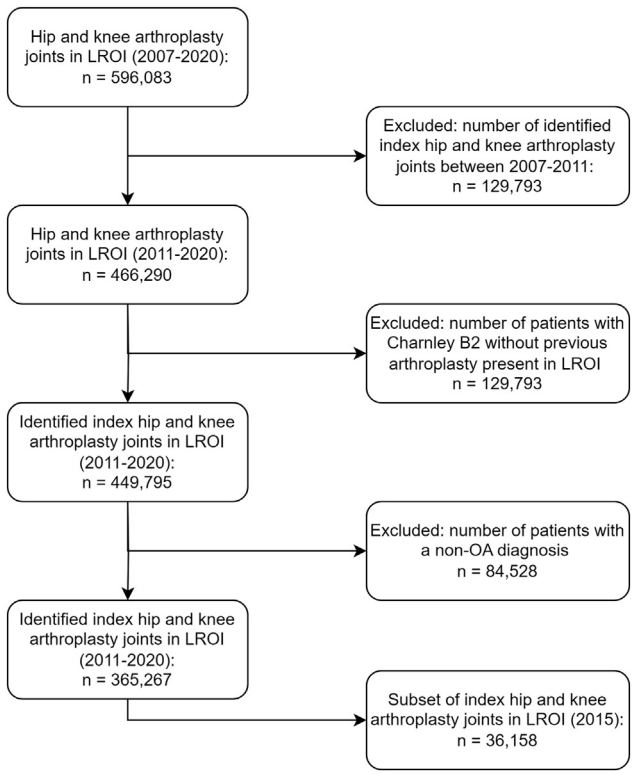


**Fig. 1.** Flowchart of patient inclusion and exclusion HA, Hip Arthroplasty; KA, Knee Arthroplasty; LROI, Dutch Arthroplasty Register; OA, Osteoarthritis; Charnley score B2 = presence of a self-reported previous arthroplasty.

**Table 1**
Patient Demographics of Patients Who Have a Primary Index Hip Arthroplasty.

| Demographics | Number of Joint Arthroplasties (N = Number of Joint Arthroplasties) | | | | |
|---|---|---|---|---|---|
| | 1 (N = 140,406) | 2 (N = 37,245) | 3 (N = 2,350) | 4 (N = 326) | Total (N = 180,327) |
| Sex | | | | | |
| Woman | 88,454 (63.1%) | 25,763 (69.2%) | 1,790 (76.2%) | 260 (79.8%) | 116,267 (64.5%) |
| N-missing | 169 | 24 | 1 | 0 | 194 |
| BMI | | | | | |
| Mean (SD) | 27.2 (4.4) | 27.5 (4.5) | 29.2 (4.8) | 29.0 (4.5) | 27.3 (4.5) |
| N-missing | 34,708 | 12,815 | 1,141 | 182 | 48,846 |
| BMI categories[a] | | | | | |
| Under weight ( ≤ 18.5) | 763 (0.7%) | 152 (0.6%) | 1 (0.1%) | 0 (0.0%) | 916 (0.7%) |
| Normal weight (18.5-25) | 35,885 (34.0%) | 7,743 (31.7%) | 238 (19.7%) | 25 (17.4%) | 43,891 (33.4%) |
| Over weight (25-30) | 45,129 (42.7%) | 10,489 (42.9%) | 526 (43.5%) | 66 (45.8%) | 56,210 (42.8%) |
| Obese (30-40) | 22,840 (21.6%) | 5,764 (23.6%) | 405 (33.5%) | 51 (35.4%) | 29,060 (22.1%) |
| Morbid obese (>40) | 1,081 (1.0%) | 282 (1.2%) | 39 (3.2%) | 2 (1.4%) | 1,404 (1.1%) |
| N-missing | 34,708 | 12,815 | 1,141 | 182 | 48,846 |
| Age | | | | | |
| Mean (SD) | 69.5 (10.1) | 67.7 (9.3) | 68.0 (8.0) | 66.6 (7.9) | 69.1 (9.9) |
| N-missing | 131 | 21 | 1 | 0 | 153 |

SD, standard deviation; BMI, Body mass index (kg/m$^2$).
[a] BMI was recorded from 2014 onwards.

*Study Population*

From 2007 until 2020, 596,083 patients were registered with a primary hip or KA in the LROI. A total of 129,793 patients who have a previously registered arthroplasty (between 2007 and 2011) were excluded. Of the remaining 466,290 patients, 16,495 were excluded based on self-reported previous arthroplasty according to the Charnley classification. This resulted in 365,267 index arthroplasty patients who had an indication for OA (Figure 1). The mean age of the patients in the HA population was 69 (standard deviation (SD): 9.9) years old; 65% of the patients were women and had a mean body mass index (BMI) of 27 (SD: 4.5) (Table 1). The mean age in the knee population was 67 (SD: 9.3) years, with 62% women and a mean BMI of 29 (SD: 4.9) (Table 2).

*Patient Characteristics*

Patients' characteristics that were collected at the time of primary surgery were age, sex, BMI (available from 2014 onwards), current smoking status (yes/no; available from 2014 onwards), and the American Society of Anesthesiologists physical function (ASA) score as an assessment of the patient's overall health (I – normal health to IV- severe systemic disease; considering surgery in patients who have ASA I to IV).

*PROs*

Data on PROs were collected using questionnaires that were filled out before surgery and postoperatively at three (HA) or six (KA) months, and one year (both HA and KA). These questionnaires included the Hip Disability and Osteoarthritis Outcome Score Short Form (HOOS-PS; 0 best to 100 worst), and the Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS; 0 best to 100 worst). and Numerical Rating Scales (NRS) for pain during rest and activities during the past 7 days, both ranging from 0 (no pain) to 10 (worst pain) [20–22]. Minimal Clinical Important Difference for Hip Disability and Osteoarthritis Outcome Score Short Form and Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form was set at 10 points [23,24]. Minimal Clinical Significant Difference for the NRS pain scores was set at 1.4 points [25].

**Table 2**
Patient Demographics – Patient Demographics of Patients Who Have a Primary Index Knee Arthroplasty.

| Demographics | Number of Joint Arthroplasties (N = Number of Joint Arthroplasties) | | | | |
|---|---|---|---|---|---|
| | 1 (N = 140,268) | 2 (N = 41,802) | 3 (N = 2,513) | 4 (N = 357) | Total (N = 184,940) |
| Sex | | | | | |
| Women | 84,274 (60.2%) | 27,307 (65.4%) | 1,851 (73.8%) | 272 (76.2%) | 113,704 (61.6%) |
| N-missing | 278 | 57 | 5 | 0 | 340 |
| BMI | | | | | |
| Mean (SD) | 29.3 (4.8) | 30.2 (5.2) | 29.6 (4.8) | 29.6 (5.1) | 29.4 (4.9) |
| N-missing | 31,609 | 13,768 | 1,275 | 205 | 46,857 |
| BMI categories[a] | | | | | |
| Under weight ( ≤ 18.5) | 175 (0.2%) | 30 (0.1%) | 1 (0.1%) | 0 (0.0%) | 206 (0.1%) |
| Normal weight (18.5-25) | 20,118 (18.5%) | 4,149 (14.8%) | 211 (17.0%) | 26 (17.1%) | 24,504 (17.7%) |
| Over weight (25-30) | 46,657 (42.9%) | 11,172 (39.9%) | 509 (41.1%) | 64 (42.1%) | 58,402 (42.3%) |
| Obese (30-40) | 38,779 (35.7%) | 11,440 (40.8%) | 481 (38.9%) | 56 (36.8%) | 50,756 (36.8%) |
| Morbid obese (>40) | 2,930 (2.7%) | 1,243 (4.4%) | 36 (2.9%) | 6 (3.9%) | 4,215 (3.1%) |
| N-missing | 31,609 | 13,768 | 1,275 | 205 | 46,857 |
| Age | | | | | |
| Mean (SD) | 67 (9.5) | 66 (8.8) | 68 (8.3) | 66 (7.8) | 67 (9.3) |
| N-missing | 122 | 23 | 0 | 0 | 145 |

SD, standard deviation; BMI, Body mass index (kg/m$^2$).
[a] BMI was recorded from 2014 onwards.

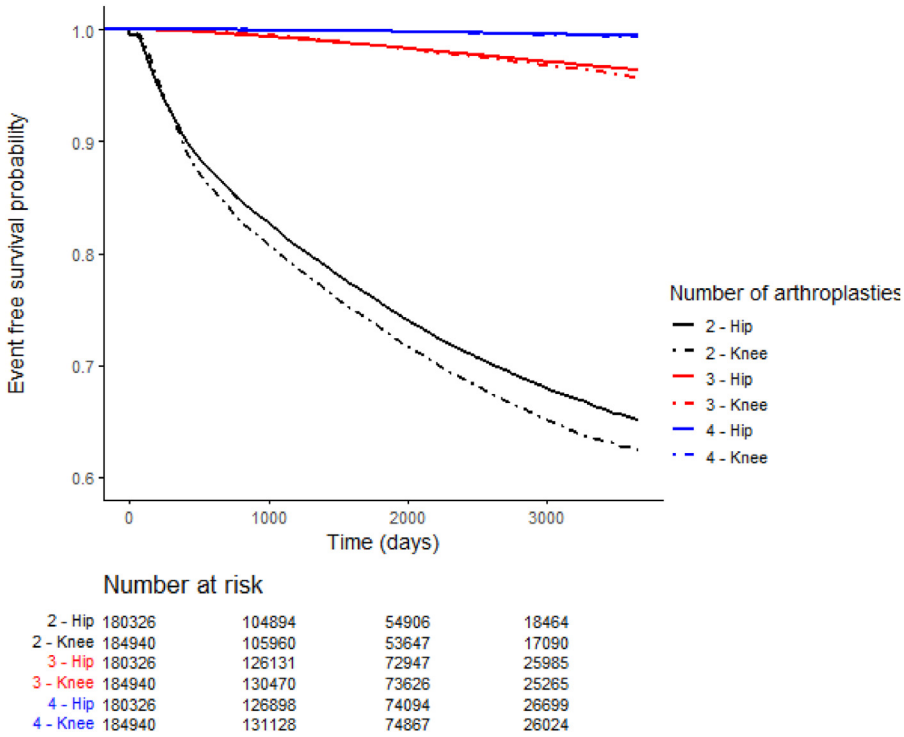


**Fig. 2.** Cumulative incidence for 2, 3 and 4 arthroplasties stratified for initial joint (Hip = solid, Knee = dot dash). The 95% confidence interval was not visually distinguishable from the probability lines, it was, therefore, not plotted.

*Data Analyses*

All analyses, except the ordinal logistic regression on risk factors, were stratified by index joint (hip or knee). To assess the 1, 2, 5, and 10-year $C_{in}$ based on the index joint, we calculated the occurrence of subsequent arthroplasties while accounting for the competing risk of death. To visualize the results, a Kaplan-Meier was plotted, and event-free survival probabilities using additional arthroplasty as the event were calculated. Furthermore, for each individual patient, the time between subsequent arthroplasties was calculated to determine the mean time intervals between arthroplasties. In addition, the number of patients who have a certain sequence of arthroplasties (eg, left hip followed by a right hip, followed by the left knee) was calculated to assess the frequency of different MJA trajectories. Ordinal logistic regressions were performed to investigate if certain patient characteristics were associated with the number of arthroplasties. Sex (men as the reference category), age (continuous), BMI (continuous), and index joint were used as independent factors. To compare postoperative PROs in the first year after the index joint regarding function and pain between patients who had MJA and SJA, linear mixed models including a random intercept and interaction term (Timing PRO assessment * presence or absence of MJA) were performed, while adjusting for possible confounders (age, sex, BMI). All analyses were performed in R (version 3.6.3) (Posit PBC, Boston, Massachusetts, United States).

**Table 3**
Multiple Joint Arthroplasties Cumulative Incidence With Competing Risk of Death.

| Hip (Index Joint) | 2+ Arthroplasties | 3+ Arthroplasties | 4 Arthroplasties |
|---|---|---|---|
| Time (d) | Risk (95% CI) | Risk (95% CI) | Risk (95% CI) |
| 1 Y (365) | 8.9% (8.7 to 9.0%) | 0.1% (0.1 to 0.1%) | 0.01% (0 to 0.01%) |
| 2 Y (730) | 14.3% (14.1 to 14.5%) | 0.4% (0.4 to 0.4%) | 0.02% (0.02 to 0.03%) |
| 5 Y (1,825) | 24.0% (23.74 to 24.2%) | 1.4% (1.4 to 1.5%) | 0.14% (0.12 to 0.16%) |
| 10 Y (3,650) | 32.7% (32.2 to 33.1%) | 3.2% (3.0 to 3.3%) | 0.47% (0.41 to 0.54%) |
| **Knee (index joint)** | **2+ arthroplasties** | **3+ arthroplasties** | **4 arthroplasties** |
| Time (d) | Risk (95% CI) | Risk (95% CI) | Risk (95% CI) |
| 1 Y (365) | 9.5% (9.4 to 9.7%) | 0.1% (0.1 to 0.1%) | 0.00% (0.00 to 0.00%) |
| 2 Y (730) | 16.0% (15.9 to 16.2%) | 0.3% (0.3 to 0.3%) | 0.01% (0.01 to 0.02%) |
| 5 Y (1,825) | 26.4% (26.1 to 26.6%) | 1.5% (1.4 to 1.5%) | 0.15% (0.13 to 0.17%) |
| 10 Y (3,650) | 35.8% (35.4 to 36.3%) | 3.8% (3.6 to 4.1%) | 0.57% (0.48 to 0.65%) |

2+ arthroplasties (and 3+) is defined so that all patients receiving a second or more (and 3 or more) arthroplasties after their initial hip or knee arthroplasty are classified as having the event with a time at risk from first to subsequent arthroplasty.
CI, Confidence interval.

**Table 4**
Mean Time Interval Between Arthroplasties in Months.

| Joints | Time Interval Between Arthroplasties (mo) | | |
|---|---|---|---|
| | first and second | first and third | first and fourth |
| Hip (index joint) | | | |
| Mean (95% CI) | 26.3 (26.1 to 26.7) | 47.4 (46.4 to 48.4) | 58.3 (55.4 to 61.1) |
| Median (range) | 17.5 (0 to 119.5) | 44.1 (0 to 117.8) | 58.7 (3.1 to 113.5) |
| Knee (index joint) | | | |
| Mean (95% CI) | 26.1 (25.9 to 26.3) | 51.7 (50.8 to 52.7) | 60.9 (58.3 to 63.4) |
| Median (range) | 16.8 (0 to 119.5) | 49.9 (0.1 to 118.1) | 60.3 (8.3 to 116.3) |

CI, Confidence Interval.

## Results

### *Cumulative Incidence*

The 1, 2, 5, and 10-year $C_{in}$ for MJA are depicted in Figure 2 and Table 3. The 10-year $C_{in}$ for a second arthroplasty was 32.7% (95% CI [32.2 to 33.1]) after an index HA and 35.8% (95% CI [35.4 to 36.3]) after index KA (Figure 2 and Table 3). The 10-year $C_{in}$ for > 3 and > 4 joint arthroplasties were < 4% after both index hip and KA.

### *Mean Time-Intervals*

For HA patients, the mean time intervals between the first and subsequent second, third, and fourth arthroplasty were 26.3 (95% CI: 26.1 to 26.7), 47.4 (95% CI: 46.4 to 48.4), and 58.3 (95% CI: 55.4 to 61.1) months, respectively. For KA patients these numbers were 26.1 (95% CI: 25.9 to 26.3), 51.7 (95% CI: 50.8 to 52.7), and 60.9 (95% CI: 58.3 to 63.4) months (Table 4).

### *Arthroplasty Trajectories*

A total of 84,593 (43%) of index hip and knee patients received a second arthroplasty. Of the patients receiving a second arthroplasty, 83% received a second arthroplasty in the contralateral cognate joint (Figure 3). The group that received an arthroplasty in the contralateral cognate joint as a second arthroplasty had the lowest risk of receiving a third arthroplasty (1.53% for index HA and 1.82% for index KA). The most often followed sequence was index (eg, HA right), cognate (eg, HA left), noncognate contralateral (eg, KA left), noncognate ipsilateral (eg, KA right), or a shorter version of this path, if < 4 joint arthroplasties. Percentages for the complete path were low (0.05% for index hip and 0.02% for the index knee). Other trajectories showed no clear patterns.

### *Patient Characteristics*

After analyzing the patient's characteristics, the odds of MJA significantly increased among women (OR 1.33, 95% CI [1.3 to 1.4]), patients who had a higher BMI (OR 1.02, 95% CI [1.02 to 1.03]), and younger patients (OR 0.99, 95% CI [0.98 to 0.99]) (Table 5).

### *Patient-Reported Outcomes*

A total of 36,158 joints were included in this analysis (Supplementary Table 1). Functional scores in the hip population

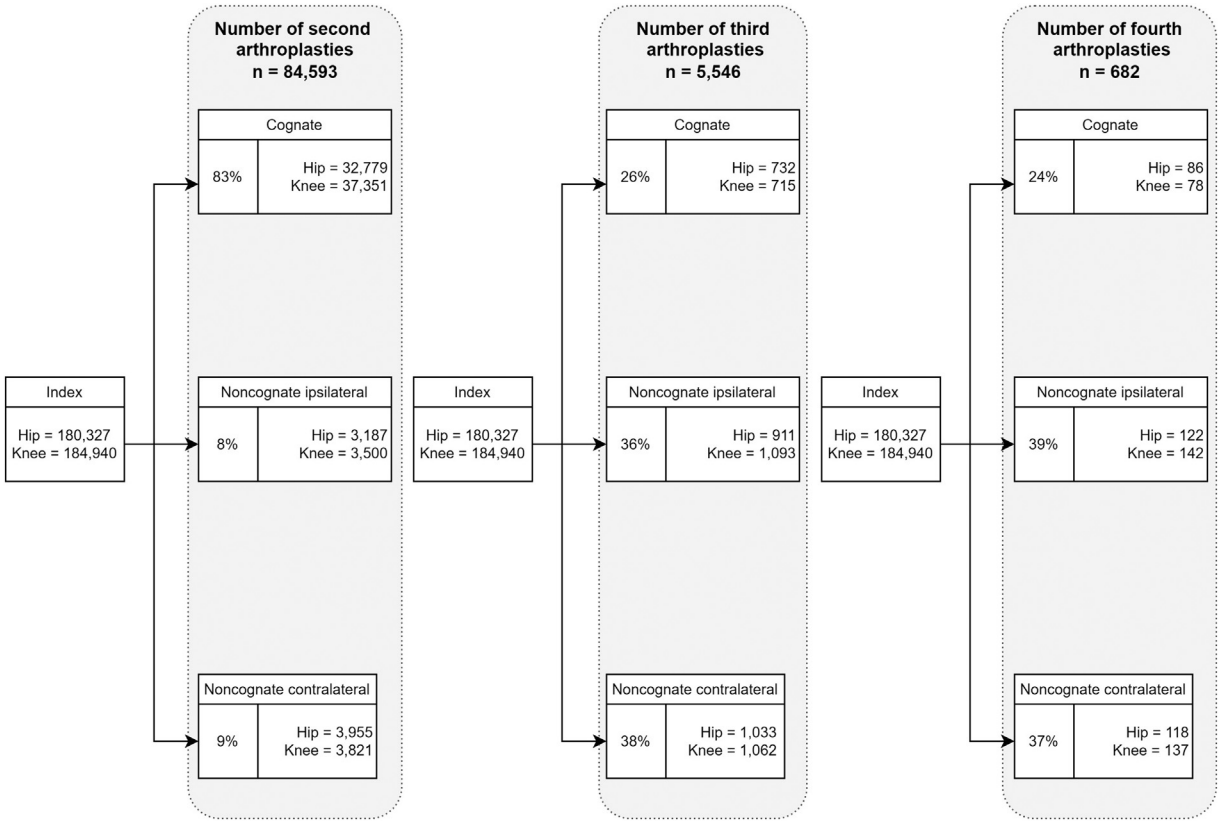


**Fig. 3.** Arthroplasty-trajectories Numbers in boxes represent absolute numbers of patients and percentages represent the total number of the box divided by the total number of patients who had a second, third, or fourth MJA.

**Table 5**
Association Between Patient Characteristics and Multiple Joint Arthroplasties (2015 Subset, n = 36,158; SJA n = 26,042, MJA n = 10,116).

| Factors | OR (95% CI) |
|---|---|
| Women | 1.33 (1.27 to 1.40) |
| BMI | 1.02 (1.02 to 1.03) |
| Age | 0.99 (0.98 to 0.99) |
| Knee index joint | 1.01 (0.96 to 1.06) |
| Intercepts | |
| 1->2 | 2.17 |
| 2->3 | 41.827 |
| 3->4 | 381.073 |

OR, Odds Ratio; CI, Confidence Interval; BMI, Body mass index (kg/m$^2$).

were lower in MJA patients at 3 months (−3.3, 95% CI [−4.5 to −2.1]) and 12 months (−2.4, 95% CI [−3.6 to −1.3]) compared to SJA (Table 6). Additionally, the model including the pain scores showed that MJA patients scored lower on the NRS pain scales during activity (3 months: −0.4, 95% CI [−0.6 to −0.3]; 12 months: −0.4, 95% CI [−0.5 to −0.2]) and in rest (3 months: −0.4, 95% CI [−0.5 to −0.2]; 12 months: −0.4, 95% CI [−0.5 to −0.2]). Similar outcomes were found in the index knee population. The PROs postoperatively significantly differed in patients who have MJA and SJA; the differences found were small and not clinically relevant based on the Minimal Clinical Important Difference.

## Discussion

We investigated the $C_{in}$ of MJA. We also assessed the time between the first lower joint arthroplasty and subsequent lower joint arthroplasty and the frequency of MJA trajectories. Furthermore, we compared patient characteristics and postoperative PROs between MJA and SJA patients. The results of this study showed that the 10-year $C_{in}$ for a second arthroplasty (HA or KA) was 33% after an index primary HA and 36% after an index primary KA. Only a few patients received more than two arthroplasties during a 10-year period. If a patient received a second arthroplasty, it was most often the contralateral cognate joint (83%). Furthermore, the intervals between the first and second, third, and fourth arthroplasty were approximately 2, 4, and 5 years, respectively. We found that women patients who have a higher BMI and younger patients were at greater risk of receiving MJA. Also, postoperative patient-reported outcomes seemed clinically comparable between patients who have MJA and SJA.

Previous literature reported prevalence or used other time periods to assess the $C_{in}$, which makes comparison of results difficult. Espinosa et al. [3] reported that the average time interval for a second arthroplasty was 3.1 years after index KA and 4.0 years after index HA. This study showed that, on average, 2.2 years were between the first and subsequently second arthroplasty. Furthermore, previous studies reported 20-year $C_{in}$s between 29 and 45% [3–5]. The 10-year $C_{in}$s for subsequent hip and KA in this study were 33% in index hip and 36% in index knee patients. This corresponds to the findings of previous studies [6–9] regarding the 10-year risk of subsequent arthroplasty. Regarding the patient characteristics associated with MJA as compared to SJA, our study is in accordance with previous studies that identified various risk factors for a second arthroplasty, such as younger age, being more obese, and women [3–5,26]. Different from this study, these studies also found that an index TKA joint was a risk factor for MJA.

Although THA and TKA are known to alleviate symptoms associated with OA, about 15 to 20% of these arthroplasty patients do not improve as expected or are unsatisfied with the results after this elective surgical procedure [27–29]. A multitude of factors have been mentioned for this, varying from preoperative incapacitating pain with little radiological OA to expectations on the effect of arthroplasty [28,30,31]. Despite the

**Table 6**
Difference in Patient Reported Outcome Measures Between Single and Multiple Joint Arthroplasty Patients[a].

| Patient Reported Outcome Measures | N | Crude | N | Adjusted[a] |
|---|---|---|---|---|
| | | Coefficients (95% CI) | | Coefficients (95% CI) |
| Hip patient | | | | |
| HOOS-PS | 7,662 | | 7,607 | |
| Baseline | | 2.5 (1.6 to 3.3) | | 2.1 (1.3 to 3.0) |
| 3 mo postoperative | | −3.3 (−4.5 to −2.1) | | −3.3 (−4.5 to −2.1) |
| 12 mo postoperative | | −2.5 (−3.6 to −1.3) | | −2.4 (−3.6 to −1.3) |
| Pain during activity | 7,844 | | 7,787 | |
| Baseline | | 0.2 (0.1 to 0.3) | | 0.16 (0.1 to 0.3) |
| 3 mo postoperative | | −0.4 (−0.6 to −0.3) | | −0.4 (−0.6 to −0.3) |
| 12 mo postoperative | | −0.4 (−0.5 to −0.2) | | −0.4 (−0.5 to −0.2) |
| Pain during rest | 7,826 | | 7,769 | |
| Baseline | | 0.3 (0.2 to 0.4) | | 0.2 (0.1 to 0.4) |
| 3 mo postoperative | | −0.4 (−0.5 to −0.2) | | −0.4 (−0.5 to −0.2) |
| 12 mo postoperative | | −0.4 (−0.5 to −0.2) | | −0.4 (−0.5 to −0.2) |
| Knee patients | | | | |
| KOOS-PS | 5,029 | | 5,019 | |
| Baseline | | 2.3 (1.2 to 3.4) | | 1.7 (0.6 to 2.8) |
| 6 mo postoperative | | −3.5 (−5.0 to −1.9) | | −3.5 (−5.0 to −1.9) |
| 12 mo postoperative | | −1.8 (−3.2 to −0.4) | | −1.8 (−3.2 to −0.5) |
| Pain during activity | 3,972 | | 3,962 | |
| Baseline | | 0.2 (−0.0 to 0.4) | | 0.12 (−0.1 to 0.3) |
| 6 mo postoperative | | −0.6 (−0.8 to −0.3) | | −0.6 (−0.8 to −0.3) |
| 12 mo postoperative | | −0.2 (−0.5 to 0.0) | | −0.2 (−0.5 to −0.0) |
| Pain during rest | 3,970 | | 3,960 | |
| Baseline | | 0.2 (0.0 to 0.4) | | 0.1 (−0.1 to 0.3) |
| 6 mo postoperative | | −0.4 (−0.7 to −0.1) | | −0.5 (−0.7 to −0.2) |
| 12 mo postoperative | | −0.3 (−0.5 to 0.0) | | −0.3 (−0.5 to −0.0) |

CI, Confidence Interval; HOOS-PS, Hip Disability and Osteoarthritis Outcome Score Short Form; KOOS-PS, Knee Injury and Osteoarthritis Outcome Score Short Form.
[a] Adjusted for sex, age and body mass index (kg/m2) measured for index joint, with an interaction term between timing of the Patient-Reported Outcome and presence or absence of MJA.

fact that multiple joint involvement in the lower extremities alongside the single joint indicated for surgery seems like an obvious factor, only a few patients have MJA. Thus, multiple joint-affected OA patients throughout a follow-up may constitute different phenotypes of patients who have a different, more inflammatory genotype of OA. Nevertheless, literature on the difference between MJA and SJA in OA patients is scarce [15,16]. Singh et al. [15] showed that ipsilateral involvement of another lower extremity joint increases the risk of poor pain and function outcomes after THA or TKA. The study by Singh et al. [15] stresses the importance of including multiple joint involvements of the lower extremities.

Although it was expected that MJA would affect outcomes, the current study only shows significantly worse outcomes in MJA patients compared to SJA patients during the first postoperative year. Nevertheless, these differences were not clinically relevant. Within the LROI, patients receive postoperative questionnaires until one year after surgery. This might explain the findings of this current study. Additionally, the present study showed that, on average, patients receive their second arthroplasty approximately 2 years after their index joint. As a result, symptoms regarding the second joint might not significantly impact the PROs of the index joint at 1-year postoperatively.

We identified the following potential limitations based on the study design: Within this study, MJA patients were identified in retrospect. Therefore, patients had to survive until their subsequent joint arthroplasty to be identified as MJA patients. This might have introduced immortal time bias, which could have diluted our results. Additionally, we did not address planned staged bilateral arthroplasty separately, as this information is not available in the Dutch Arthroplasty Register. Planned staged bilateral arthroplasties could have affected the outcomes of the PROs in the MJA group. It is, therefore, important that information regarding these procedures be included in future research on this topic. Also, no information was available on the stage of OA disease in the hip and knee joints, and as such, we were not able to quantify the severity of OA in the index joint and the other joints at the time of surgery.

This study provides estimates of the yearly incidence, different MJA-trajectories, and time intervals between index and successive joint arthroplasties in patients who have a HA or KA. Knowledge of these numbers is warranted to estimate whether MJA involvement affects postoperative outcomes in registers. Taking into consideration the increased risk of successive joint arthroplasties in women, patients who have a higher BMI, and at a younger age, this provides orthopaedic surgeons and patients who have additional information regarding the possible progression of OA in the lower extremities. Hence, this information can be used in clinical practice to provide necessary information for orthopaedic surgeons as well as improve health outcomes and care processes for the patient. It aids in expectation management, thereby leading to improved postoperative outcomes, satisfaction, and quality of care.

## Conclusion

The MJA patients occupy a considerable proportion of the population receiving HA or KA. Irrespective of the index joint arthroplasty, the odds of receiving MJA significantly increased among women, patients who had a higher BMI and younger age, and postoperative outcomes were slightly negatively affected by MJA. With the results of this large nationwide study, patients and physicians can be more accurately informed about the probability and possible prospects of MJA.

## CRediT authorship contribution statement

**Daisy A.J.M. Latijnhouwers:** Writing – original draft, Visualization, Validation, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Jip A. van Gils:** Writing – original draft, Visualization, Formal analysis. **Thea P.M. Vliet Vlieland:** Writing – review & editing. **Liza N. van Steenbergen:** Writing – review & editing, Project administration, Data curation. **Perla J. Marang – van de Mheen:** Writing – review & editing, Conceptualization. **Suzanne C. Cannegieter:** Writing – review & editing. **Suzan H.M. Verdegaal:** Writing – review & editing. **Rob G.H.H. Nelissen:** Writing – review & editing. **Maaike G.J.Gademan:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

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## Appendix

**Supplementary Table 1**
Demographics of the 2015 Subset of Patients who have Single Joint Arthroplasty and Multiple Joint Arthroplasties.

| Demographics | Count TJA (N(%)[a] of patients) | | | |
|---|---|---|---|---|
| | 1 (N = 26,042) | 2 (N = 9,470) | 3 (N = 578) | 4 (N = 68) |
| Sex | | | | |
| Women | 15,805 (60.7%) | 6,300 (66.6%) | 429 (74.2%) | 49 (72.1%) |
| N-missing | 14 | 4 | 0 | 0 |
| BMI | | | | |
| Mean (SD) | 28.24 (4.8) | 28.96 (5.1) | 29.41 (4.6) | 29.77 (5.2) |
| N-missing | 297 | 104 | 14 | 1 |
| BMI categories | | | | |
| Under weight ( $\leq$ 18.5) | 132 (0.5%) | 34 (0.4%) | 1 (0.2%) | 0 (0.0%) |
| Normal weight (18.5-25) | 6,713 (26.1%) | 2084 (22.3%) | 98 (17.4%) | 12 (17.9%) |
| Overweight (25-30) | 11,095 (43.1%) | 3,868 (41.3%) | 242 (42.9%) | 25 (37.3%) |
| Obese (30-40) | 7,283 (28.3%) | 3,092 (33.0%) | 210 (37.2%) | 28 (41.8%) |
| Morbid obese (>40) | 522 (2.0%) | 288 (3.1%) | 13 (2.3%) | 2 (3.0%) |
| N-missing[b] | 297 | 104 | 14 | 1 |
| Age | | | | |
| Mean (SD) | 68 (10.0) | 67 (9.1) | 68 (7.7) | 66 (8.7) |
| N-missing[b] | 15 | 2 | 0 | 0 |
| Joint | | | | |
| Hip | 12,981 (49.8%) | 4,380 (46.3%) | 269 (46.5%) | 33 (48.5%) |
| Knee | 13,061 (50.2%) | 5,090 (53.7%) | 309 (53.5%) | 35 (51.5%) |
| Type of prothesis | | | | |
| Total joint arthroplasty | 24,378 (93.6%) | 8,840 (93.4%) | 553 (95.7%) | 66 (97.1%) |
| Hemi-/uni prosthesis | 1,545 (5.93%) | 600 (6.34%) | 23 (3.98%) | 2 (2.94%) |
| Resurfacing prothesis | 11 (0.04%) | 2 (0.02%) | 0 (0%) | 0 (0%) |
| Patellofemoral prothesis | 103 (0.4%) | 23 (0.24%) | 0 (0%) | 0 (0%) |
| Other | 5 (0.0%) | 1 (0.0%) | 0 (0%) | 0 (0%) |
| N-missing | 0 | 4 | 2 | 0 |
| Baseline HOOS-PS | | | | |
| Mean (SD) | 48.2 (18.0) | 50.5 (17.9) | 52.4 (19.2) | 49.4 (25.7) |
| N-missing | 21,438 | 7,849 | 472 | 56 |
| Baseline KOOS-PS | | | | |
| Mean (SD) | 50.7 (14.9) | 52.9 (14.5) | 53.6 (16.3) | 70.2 (30.6) |
| N-missing | 23,957 | 8,682 | 529 | 66 |
| Baseline pain during activities | | | | |
| Mean (SD) | 7.1 (2.0) | 7.3 (2.0) | 7.4 (2.1) | 7.6 (2.0) |
| N-missing | 19,148 | 7,019 | 416 | 52 |
| Baseline pain at rest | | | | |
| Mean (SD) | 4.9 (2.6) | 5.2 (2.6) | 5.4 (2.6) | 4.9 (2.9) |
| N-missing | 19,164 | 7,026 | 416 | 52 |

BMI, body mass index (kg/m$^2$); SD, standard deviation; HOOS-PS; Hip Disability and Osteoarthritis Outcome Score short form; KOOS-PS, Knee Injury and Osteoarthritis Outcome Score short form.

[a] Or otherwise as indicated.

[b] BMI was recorded from 2014 onwards.