



# BMJ Open UK poSt Arthroplasty Follow-up rEcommendations (UK SAFE): what does analysis of linked, routinely collected national data sets tell us about mid-late term revision risk after hip replacement? Retrospective cohort study

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## ABSTRACT

**Objective** To identify patients at risk of mid-late term revision of hip replacement to inform targeted follow-up.

**Design** Analysis of linked national data sets from primary and secondary care (Clinical Practice Research Datalink (CPRD-GOLD); National Joint Registry (NJR); English Hospital Episode Statistics (HES); Patient-Reported Outcome Measures (PROMs)).

**Participants** Primary elective total hip replacement (THR) aged ≥18.

**Event of interest** Revision surgery ≥5 years (mid-late term) after primary THR.

**Statistical methods** Cox regression modelling to ascertain risk factors of mid-late term revision. HR and 95% CI assessed association of sociodemographic factors, comorbidities, medication, surgical variables and PROMs with mid-late term revision.

**Results** NJR-HES-PROMs data were available from 2008 to 2011 on 142 275 THR; mean age 70.0 years and 61.9% female. CPRD GOLD-HES data covered 1995–2011 on 17 047 THR; mean age 68.4 years, 61.8% female. Patients had minimum 5 years postprimary surgery to end 2016. In NJR-HES-PROMs data, there were 3582 (2.5%) revisions, median time-to-revision after primary surgery 1.9 years (range 0.01–8.7), with 598 (0.4%) mid-late term revisions; in CPRD GOLD, 982 (5.8%) revisions, median time-to-revision 5.3 years (range 0–20), with 520 (3.1%) mid-late term revisions.

Reduced risk of mid-late term revision was associated with older age at primary surgery (HR: 0.96; 95% CI: 0.95 to 0.96); better 6-month postoperative pain/function scores (HR: 0.35; 95% CI: 0.27 to 0.46); use of ceramic-on-ceramic (HR: 0.73; 95% CI: 0.56 to 0.95) or ceramic-on-polyethylene (HR: 0.76; 95% CI: 0.58 to 1.00) bearing surfaces.

Increased risk of mid-late term revision was associated with the use of antidepressants (HR: 1.32; 95% CI: 1.09 to 1.59), glucocorticoid injections (HR: 1.33; 95% CI: 1.06 to 1.67) and femoral head size ≥44 mm (HR: 2.56; 95% CI: 1.09 to 6.02)

## Strengths and limitations of this study

- This study is part of a wider programme of work to identify potential patient groups for follow-up after hip and knee replacement and used large national routine data sets from primary and secondary care.
- The linkage of data sets allowed us to explore the impact of multiple risk factors on the mid-late term risk of revision of hip replacement.
- This study identifies predictors of mid-late term revision risk for hip replacement from real-world data and contributes to the discussion on follow-up.
- A limitation of the National Joint Registry for England, Wales, Northern Ireland and the Isle of Man, the Hospital Episode Statistics and Patient-Reported Outcome Measures linked data was limited long-term follow-up—only data from 2009 to 2011 could be included to allow for revision rates at least 5 years after primary surgery.
- Data were missing for some of the variables in our data sets and this required us to use imputation to account for this in our analyses.

No association of gender, obesity or Index of Multiple Deprivation was observed.

**Conclusion** The risk of mid-late term THR is associated with age at primary surgery, 6-month postoperative pain and function and implant factors. Further work is needed to explore the associations with prescription medications observed in our data.

## INTRODUCTION

Total hip replacement (THR) continues to provide many thousands of patients each year with a clinically effective treatment for end stage osteoarthritis of the hip joint. The surgical procedure has been shown to produce good outcomes for the patient and

to be cost effective.<sup>1</sup> The latest report from the National Joint Registry for England, Wales, Northern Ireland (NJR) and the Isle of Man recorded over 100 000 hip replacements in the preceding year;<sup>2</sup> the lifetime risk of undergoing a THR is estimated to be 11.6% for women and 7.1% for men.<sup>3</sup> Although it is a highly successful procedure, the cost associated with THR places an increasing burden on healthcare resources of funding and capacity, and the numbers are projected to grow with an ageing and increasingly obese population.<sup>4</sup>

Until relatively recently, care for patients with a THR included follow-up over the longer term; British Orthopaedic Association guidelines recommended outpatient follow-up at 1 and 7 years, and every 3 years thereafter for implants with well-documented survival statistics, namely the Orthopaedic Data Evaluation Panel 10A implants.<sup>5</sup> These services were intended to provide early detection of patients with failing implants. However, many hospitals face pressure to reduce the number of outpatient appointments due to longer waiting lists for orthopaedic treatment and there is evidence that follow-up services have been declining for some time.<sup>6</sup> With the additional challenges of the COVID-19 pandemic, waiting lists for orthopaedic treatment have increased further, placing additional pressure on outpatient services.<sup>7</sup> In the current healthcare environment where outpatient services face multiple threats, evidence is needed of the impact of disinvestment on follow-up of THR.

Although current evidence suggests that the proportion of THR that require a revision surgery is relatively low (7.53% at 15 years), the patient experience and costs vary with the cause of revision.<sup>2 8</sup> Periprosthetic fractures, which occur when the bone fractures adjacent to the THR, are one of the most expensive and traumatic categories, and it is estimated that numbers of this type of revision surgery are increasing.<sup>9</sup> As disinvestment in follow-up services has a potential effect on patient safety through early detection of failing implants, it is of interest to identify those groups of patients who may be at increased risk of revision of THR if no follow-up is provided. The James Lind Alliance work with groups of patients, public and health professionals to establish priorities in research.<sup>10</sup> In March 2014, they established that defining the ideal postoperative period and the best long-term model of care were among the top 10 priorities for people with osteoarthritis and a hip replacement. This emphasises a need to identify which patient groups will be most impacted by disinvestment in follow-up services.

This study forms part of a larger research programme, UK SAFE, that was designed to address the research question: Is it safe to disinvest in mid-late term follow-up of hip and knee replacement? (see protocol in online supplemental file 1).<sup>11</sup> The UK SAFE programme consisted of four work-packages using a mixed-methods design and took place between 1 December 2016 and 30 November 2020. The aim of this study (one of the four) was to identify which groups of patients with THR may require

follow-up based on their mid-late term revision risk, five or more years postprimary surgery.

## METHODS

### Study design

This was an observational retrospective study based on existing national primary care and linked secondary care data sets aiming to identify factors that may be predictive for revision of hip replacement. The data sets included the Clinical Practice Research Datalink (CPRD) GOLD, the NJR, the Hospital Episode Statistics (HES) and Patient-Reported Outcome Measures (PROMs) for hip replacement.

### Sources of data

#### CPRD GOLD-HES

The CPRD GOLD comprises the entire computerised medical records of a sample of patients attending general practitioners (GPs) in the UK.<sup>12</sup> It contains information on over 14 million patients registered at over 700 general practices in the UK that are representative of the population in terms of demographics such as age and sex.<sup>13</sup> The CPRD is administered by the Medicines and Healthcare products Regulatory Agency (MHRA). GPs in the UK play a key role in the delivery of healthcare, and each GP practice records any available medical information for their registered patients. This includes all clinical and referral events in both primary and secondary care in addition to comprehensive demographic information, prescription data and hospital admissions. Data are stored using Read codes<sup>14</sup> for diseases that are cross-referenced to the International Classification of Diseases (ICD-10).<sup>15</sup> Read codes are used as the standard clinical terminology system within UK primary care. Only practices that pass quality control are used as part of CPRD GOLD. CPRD ensures patient confidentiality by providing anonymised healthcare records.

CPRD GOLD data were linked to data for all-cause mortality, provided by the Office for National Statistics (ONS).<sup>16</sup> CPRD GOLD data were also linked to the Index of Multiple Deprivation (IMD) and to the HES database (described later). CPRD already provide access to HES data for England that is held under the CPRD Data Linkage Scheme, available for around 60% of patients in the database.

#### NJR-HES-PROMs

Starting in 2003, the NJR collected information on all hip and knee replacements performed each year in both public and private hospitals in England, Wales, Northern Ireland and the Isle of Man.<sup>2</sup> Data are entered into the NJR using forms completed at the time of surgery, and revision operations are linked to primaries using unique patient identifiers. Data recorded in the NJR includes prosthesis and operative information (prosthesis type, approach and thromboprophylaxis); patient information (age, gender, body mass index (BMI), American Society

of Anaesthesiologists (ASA) grade); surgeon and unit information (including caseloads, public/private status).

The HES data set holds information on all patients admitted to National Health Service (NHS) hospitals in England, including diagnostic ICD codes providing information about a patient's illness or condition and NHS national clinical procedural codes (OPCS4) for surgery.<sup>17</sup> It covers a smaller geographical area than the NJR and does not include privately funded operations. However, HES provides additional information for every patient, including detailed comorbidity information and deprivation indices, and every procedure, including length of stay and need for blood transfusion or critical care. Additional records contain details of readmissions, reoperations and revisions not recorded in the NJR database. We used the Admitted Patient Care data set.

Since April 2009, PROMs have been collected on all hip replacements performed in public hospitals in England.<sup>18</sup> A health-related quality of life questionnaire (the EuroQol five domain (EQ-5D-3L)<sup>19</sup>) and a joint-specific outcome score (the Oxford Hip Score (OHS)<sup>20</sup>) are collected preoperatively and at 6 months after surgery, along with patient-reported measures of preoperative disability and postoperative satisfaction.

For this analysis, we used NJR records linked to data from the HES and PROMs databases on all hip operations.

### Participants

Anonymised records were extracted for all patients over 18 years of age if they had THR for osteoarthritis. Inflammatory arthropathies were excluded as follow-up would commonly be managed by their rheumatologist. We excluded patients who had a total joint replacement of unspecified fixation, and those with a metal-on-metal THR or a hip resurfacing procedure as these groups have specific follow-up protocols in place. In addition, the following exclusions were made to remove potential case-mix issues: diagnostic codes indicating fracture or cancer of the hip bones; other injuries due to trauma, such as transport accidents and falls; non-elective admissions; a diagnosis other than primary hip osteoarthritis.

### Primary outcome

The primary outcome was a mid-late term revision of the THR, defined as more than 5 years postprimary surgery. Revision is defined as the removal, exchange or addition of any of the components of arthroplasty. Revision before 5 years usually involves a symptomatic condition such as dislocation, infection or fracture.<sup>2</sup> The symptomatic nature will prompt the patient to seek medical help and will not be reliant on a screening service, as in follow-up clinics, to identify the failing THR.

In the NJR-HES-PROMS linked data sets, operative details are completed using the NJR data set, rather than the OPCS4 coding used by the HES data set. The NJR collects operative data using two forms, one for primary operations, and the other for revision operations. In both cases, all component labels from the surgery are attached

to the form and it is from these that the component details are collected. Revision operations are linked to primaries using unique patient identifiers and so two operations on the same knee/hip could be linked using this system. The combination of the separate coding at source and the secondary linkage gives confidence that primary and revision operations are correctly identified. In the CPRD GOLD data set, subjects with a revision surgery procedure are identified using the Read codes, and for those with HES-linked data, OPCS4 codes can be used as well.

### Predictors

#### Primary care predictors

The CPRD GOLD database provided information on age, gender, BMI, joint replaced, year of joint replacement operation, recorded diagnosis of osteoarthritis (yes/no), fracture presurgery (yes/no), calcium and vitamin D supplements, use of bisphosphonates, use of selective oestrogen receptor modulators, oral glucocorticosteroid therapy, smoking status and alcohol intake recorded closest to the date of the primary surgery, region of UK, comorbid conditions registered by the physician (asthma, malabsorptive syndromes, inflammatory bowel disease, hypertension, hyperlipidaemia, ischaemic heart disease, stroke, chronic obstructive pulmonary disease, chronic kidney failure, neoplasms and diabetes) and use of drugs which can affect fracture risk (proton pump inhibitors, antiarrhythmics, anticonvulsants, antidepressants, anti-Parkinson drugs, statins, thiazide diuretics and anxiolytics).

#### Secondary care predictors

Patient-level characteristics available in NJR and HES and included in the analysis were age, gender, BMI, area deprivation, rurality, ethnicity, Charlson comorbidity index<sup>21</sup> (calculated from HES using ICD-10 codes) and ASA grade. Additional data from the NJR provided surgical and operative factors: whether or not a minimally invasive technique was used; annual surgeon volume/case load, operative time, grade of operating surgeon, surgical approach, patient position, implant fixation, type of mechanical or chemical thromboprophylaxis, unit type (public, private, independent sector treatment centre). Data from the PROMs database provided information on symptoms of pain, function and health-related quality of life preoperatively and at 6 months postsurgery. Pain and function were measured using the OHS. The EQ-5D-3L consists of five questions (assessing mobility, self-care, ability to conduct usual activities, degree of pain/discomfort and degree of anxiety/depression), ranging from 1 (best state) to 3 (worst state). EQ-5D-3L can be expressed as an overall index (graded from -0.594 to 1), or as ordinal responses for each category.

### Sample size

We included all patients receiving planned elective THR within a specified time period; for CPRD GOLD-HES data, the time span covered the years 1995–2017; for

NJR-HES-PROMS data, it covered the years 2009–2017, which was specified to allow the linkage with PROMs data which commenced in 2009. For both data sets we excluded patients receiving a primary joint replacement after 2011 to ensure all patients had at least 5 years follow-up, as we were interested in revisions occurring 5 years or more after the primary replacement surgery.

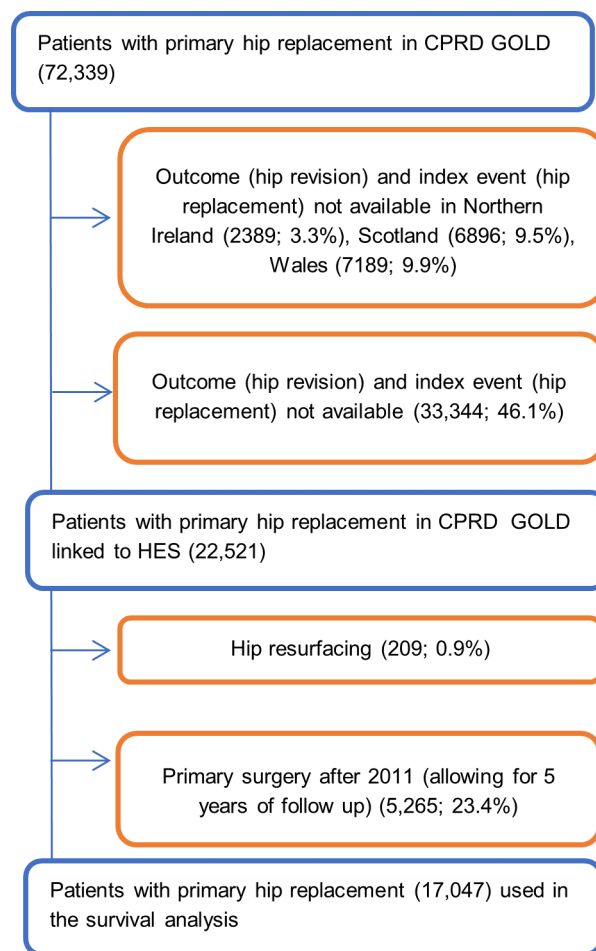
### Statistical analysis methods

Survival analysis was used to model time to revision. To identify patients most likely to require revision, proportional hazards regression modelling was used to identify preoperative, perioperative and postoperative predictors of mid-late term revision. The date of the first incidence of a subject's hip replacement was used as the start time. The event of interest in all time-to-event models was the first-recorded revision operation. Linearity of continuous predictors was assessed using fractional polynomial regression modelling. Proportionality assumptions were checked using Schoenfeld residuals. Fine and Grey regression modelling was used to account for the competing risk of death. Missing data were handled by using multiple imputation methods using the ICE (Imputation by Chained Equations) procedure.<sup>22</sup> SEs were calculated using Rubin's rules. We included all predictor variables in the multiple imputation process, together with the outcome variable (Nelson Aalen estimate of survival time and whether or not the patient had the outcome) as this carried information about missing values of the predictors.

For the CPRD GOLD-HES primary care, we generated 10 imputed data sets for THR. Data were imputed for the variables BMI, deprivation index, smoking and drinking risk factors. For secondary care NJR-HES-PROMS data set, we generated a single imputed data set for THR. Variables imputed were BMI, deprivation index, rurality, ethnicity, OHS baseline scores and EQ-5D-3L item for anxiety and depression. A full regression model was fitting including all variables, and then backward selection of variables with likelihood ratio tests was used to identify variables to keep in the final model risk factors. Fine and Grey regression models are used to account for the competing risk of death. For the CPRD GOLD-HES primary care data set, we present two final models, one with medication use as yes/no variables, and the other model with daily defined doses (DDDs) calculated from 1 year prior to the primary surgery and divided in tertiles. Harrell's C statistic is used as a measure of discriminatory ability of the survival regression models.

### Patient and public involvement

Members of the National Institute for Health Research (NIHR) Leeds Biomedical Research Centre and Bristol patient and public involvement (PPI) groups were involved in developing the UK SAFE research question and work programme based on experiences of arthroplasty and preferences for care. The steering committee includes a PPI coapplicant who has contributed to interpretation of



**Figure 1** Selection of patient data for inclusion in survival analysis. Primary care data (inclusion in blue, exclusion in orange boxes). CPRD, Clinical Practice Research Datalink; HES, Hospital Episode Statistics.

the results and will be involved in production of the final report that will be disseminated to the public, patients and NHS staff.

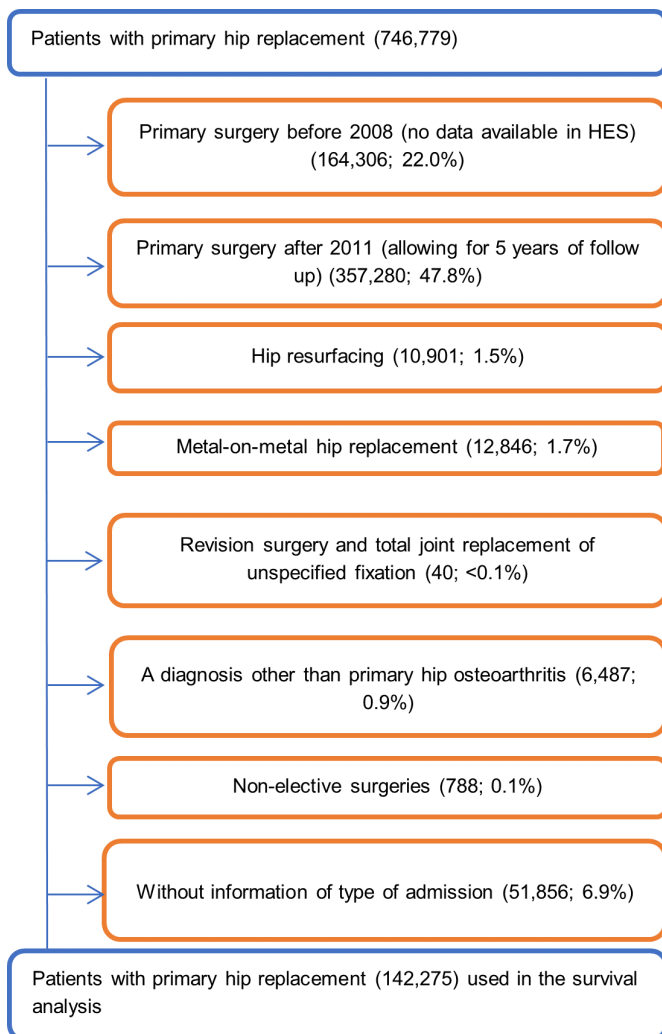
## RESULTS

### The results of this study have been reported in accordance with the STROBE checklist (supplementary file 2)

#### Participants

The extraction of records from national data sets for inclusion in data for analysis is recorded in [figure 1](#) (primary care records) and [figure 2](#) (secondary care records). The CPRD GOLD-HES data (primary) covered a longer time period from 1995 to 2011 and yielded a total of 17047 records. The NJR-HES-PROMs data (secondary) were available from 2009 to 2011 on 142 275 THR.

The age and gender distribution of patients were similar across both data sets, with a mean age of 68.4 years, 61.8% female in the CPRD GOLD-HES data, and 70.0 years, 61.9% female in the NJR-HES-PROMs data, respectively. These data, additional demographic data plus details of patient case-mix, surgical factors, operative details and primary care prescribing data are presented in online



**Figure 2** Selection of patient data for inclusion in survival analysis. Hospital data (inclusion in blue, exclusion in orange boxes). HES, Hospital Episode Statistics.

supplemental file 3: additional data (table A, CPRD-HES and table B, NJR-HES-PROMs).

The time from primary THR to revision in the CPRD GOLD-HES data was longer than in the NJR-HES-PROMs data; there were 982 (5.8%) revisions over a median time-to-revision of 5.3 years (range 0–20 years), with 520 (3.1%) mid-late term revisions. In the NJR-HES-PROMs data, there were 3582 (2.5%) revision procedures over a median time-to-revision of 1.9 years (range 0.01–8.7 years), of which 598 (0.4%) were mid-late term revisions.

### Predictors of mid-late term revision

#### Patient demographics

Older age at the time of primary operation was associated with a lower risk of mid-late revision (tables 1 and 2). The association of age was linear; for a 1-year increase in age at surgery, the risk of mid-late term revision reduced by 3% and this finding was consistent across the CPRD-HES and NJR-HES data sets. There was no association for gender, obesity or IMD deprivation on the primary outcome.

An association was observed for smoking where current smokers were at reduced risk of revision.

#### Co-morbidities

Of the comorbidities recorded in the CPRD GOLD-HES data set, two conditions were associated with increased risk of revision—malabsorption and previous non-hip fracture—and one with reduced risk—hypertension (table 1). Poorer health state at primary surgery, as indicated by ASA grade, was associated with reduced risk of revision (table 2).

#### Medication use

Analysis of preoperative medication in the CPRD GOLD-HES data (table 1) showed that the use of an antidepressant was associated with a higher revision risk. Analgesics considered for the model included narcotics (opioid pain relief) and non-narcotics, listed as non-steroidal anti-inflammatories (NSAIDs), NSAID cox (celecoxib, etoricoxib and rofecoxib), paracetamol, partial opiates and total opiates. Intra-articular glucocorticoid steroid injections were analysed as a separate predictor variable and were associated with an increased revision risk in final backwards selected regression models.

When examining associations of medication use by looking at DDDs calculated from 1 year prior to the primary surgery and divided into tertiles, further patterns emerged. The use of statins was associated with increased risk of revision in those with DDD<370 compared with no medication use. The association of injected glucocorticoid steroid use was only apparent in the higher dose category of >55 DDD (table 1).

#### Preoperative and 6-month postoperative scores

There was no association between preoperative PROMs and risk of mid-late revision. However, worse 6-month postoperative pain and function (OHS) was associated with an increased risk of revision (table 2).

#### Implant factors

Two of the implant factors in the NJR-HES-PROMs data (table 2) were associated with risk of mid-late term revision: the bearing surface and the head size. When compared with metal-on-polyethylene (MoP) implants, those patients with a ceramic-on-ceramic (CoC) or a ceramic-on-polyethylene (CoP) bearing surface had a reduced risk of outcome. Those with a femoral head size  $\geq 44$  mm were at significantly increased revision risk (table 2 and online supplemental table C), with the risk being lowest in the smaller head sizes ( $\leq 28$  mm).

#### Subgroup analysis

Within the NJR-HES-PROMS secondary care data set, analyses were repeated in the subset of patients with a MoP or CoP bearing surface (n=112 609), in order to reflect the most commonly used bearing surfaces. The variables identified in the final backward selection regression models were similar, with the exception that ASA grade was no longer selected, and comorbidities

**Table 1** Cox regression model identifying risk factors of revision after 5 years of primary total hip replacement (THR) for osteoarthritis: primary care data

| Risk factors (reference category)                                 | Patients undergoing THR (n=22312)<br>HR (95% CI); p-value |   |  |  |   |
|---|---|---|--|--|---|
|   | Crude analysis  | Adjusted analysis (drug yes/no)           | Adjusted competing risk analysis (drug yes/no) | Adjusted analysis (drug DDD)             | Adjusted competing risk analysis (drug DDD) |
| Year of primary THR (2010–2011)                                   |   |   |  |  |   |
| 1995–1999   | 4.34 (1.88 to 9.98);<br><b>p&lt;0.01</b>                  | 4.98 (2.14 to 11.59);<br><b>p&lt;0.01</b> | 7.31 (3.18 to 16.79);<br><b>p&lt;0.01</b>      | 5.02 (2.14 to 11.76);<br>p<0.01          | 7.22 (3.12 to 16.68);<br><b>p&lt;0.01</b>   |
| 2000–2004   | 2.78 (1.22 to 6.32);<br><b>p=0.02</b>                     | 3.16 (1.38 to 7.23);<br><b>p=0.007</b>    | 4.33 (1.91 to 9.80);<br><b>p&lt;0.01</b>       | 3.22 (1.40 to 7.42);<br>p=0.006          | 4.32 (1.90 to 9.83);<br><b>p&lt;0.01</b>    |
| 2005–2009   | 2.59 (1.13 to 5.91);<br><b>p=0.02</b>                     | 2.74 (1.20 to 6.28);<br><b>p=0.017</b>    | 3.46 (1.53 to 7.85);<br><b>p=0.003</b>         | 2.73 (1.19 to 6.25);<br><b>p=0.018</b>   | 3.40 (1.50 to 7.71);<br><b>p=0.003</b>      |
| Age at primary THR (continuous variable)                          | 0.97 (0.96 to 0.98);<br><b>p&lt;0.01</b>                  | 0.97 (0.96 to 0.98);<br><b>p&lt;0.01</b>  | 0.96 (0.95 to 0.96);<br><b>p&lt;0.01</b>       | 0.97 (0.96 to 0.98);<br><b>p&lt;0.01</b> | 0.96 (0.95 to 0.96);<br><b>p&lt;0.01</b>    |
| Smoking (non-smoker)  |   |   |  |  |   |
| Ex-smoker   | 1.31 (0.77 to 2.22);<br>p=0.49                            | 0.91 (0.72 to 1.17);<br>p=0.47            | 0.88 (0.69 to 1.13);<br>p=0.31                 | 0.91 (0.71 to 1.16);<br>p=0.44           | 0.88 (0.68 to 1.12);<br>p=0.29              |
| Current   | 1.31 (0.77 to 2.22);<br>p=0.58                            | 0.73 (0.54 to 0.99);<br><b>p=0.041</b>    | 0.67 (0.50 to 0.91);<br><b>p=0.01</b>          | 0.73 (0.54 to 0.98);<br><b>p=0.037</b>   | 0.67 (0.50 to 0.91);<br><b>p=0.009</b>      |
| Fracture in pelvis, proximal/humerus, wrist/forearm, spine or rib | 1.51 (0.96 to 2.40);<br>p=0.08                            | 1.68 (1.06 to 2.67);<br><b>p=0.027</b>    | 1.64 (1.04 to 2.61);<br><b>p=0.035</b>         | 1.76 (1.10 to 2.82);<br><b>p=0.018</b>   | 1.75 (1.09 to 2.79);<br><b>p=0.02</b>       |
| Comorbidities   |   |   |  |  |   |
| Malabsorption   | 4.17 (1.24 to 14.01);<br><b>p=0.02</b>                    |   |  | 3.97 (1.13 to 13.94);<br><b>p=0.032</b>  | 3.69 (1.05 to 12.95);<br><b>p=0.042</b>     |
| Hypertension  | 0.72 (0.58 to 0.89);<br><b>p&lt;0.01</b>                  | 0.77 (0.61 to 0.96);<br><b>p=0.02</b>     | 0.77 (0.62 to 0.97);<br><b>p=0.025</b>         | 0.76 (0.60 to 0.95);<br><b>p=0.014</b>   | 0.77 (0.61 to 0.96);<br><b>p=0.021</b>      |
| Antidepressants   | 1.40 (1.17 to 1.68);<br><b>p&lt;0.01</b>                  | 1.37 (1.14 to 1.65);<br><b>p=0.001</b>    | 1.32 (1.09 to 1.59);<br><b>p=0.004</b>         |  |   |
| Statins   | 1.07 (0.86 to 1.34);<br>p=0.54                            | 1.43 (1.12 to 1.81);<br><b>p=0.004</b>    | 1.37 (1.08 to 1.75);<br><b>p=0.01</b>          |  |   |
| Glucocorticoid steroid injections (intra-articular)               | 1.32 (1.06 to 1.65);<br><b>p=0.01</b>                     | 1.32 (1.06 to 1.66);<br><b>p=0.015</b>    | 1.33 (1.06 to 1.67);<br><b>p=0.014</b>         |  |   |
| DDD's 1-year prior surgery  |   |   |  |  |   |
| Bisphosphonates (no dose)   |   |   |  |  |   |
| <140 DDD  | 1.02 (0.48 to 2.16);<br>p=0.96                            |   |  | 1.16 (0.54 to 2.48);<br>p=0.70           | 0.99 (0.46 to 2.11);<br>p=0.98              |
| ≥140–340 DDD  | 0.42 (0.16 to 1.12);<br>p=0.08                            |   |  | 0.43 (0.16 to 1.17);<br>p=0.10           | 0.40 (0.15 to 1.09);<br>p=0.072             |
| >340 DDD  | 1.70 (0.84 to 3.45);<br>p=0.14                            |   |  | 2.03 (0.99 to 4.18);<br>p=0.054          | 1.77 (0.85 to 3.68);<br>p=0.13              |
| Dose missing  | 0.42 (0.11 to 1.70);<br>p=0.23                            |   |  | 0.52 (0.13 to 2.09);<br>p=0.35           | 0.43 (0.11 to 1.75);<br>p=0.24              |
| Antidepressants (no dose)   |   |   |  |  |   |
| <85 DDD   | 1.42 (0.97 to 2.06);<br>p=0.07                            |   |  | 1.35 (0.92 to 1.98);<br>p=0.12           | 1.31 (0.90 to 1.92);<br>p=0.16              |
| ≥85–365 DDD   | 1.67 (1.24 to 2.25);<br><b>p&lt;0.01</b>                  |   |  | 1.65 (1.22 to 2.24);<br><b>p=0.001</b>   | 1.57 (1.16 to 2.13);<br><b>p=0.003</b>      |
| >365 DDD  | 1.57 (0.96 to 2.59);<br>p=0.07                            |   |  | 1.56 (0.93 to 2.61);<br>p=0.089          | 1.46 (0.87 to 2.43);<br>p=0.15              |

Continued

Table 1 Continued

| Risk factors (reference category)              | Patients undergoing THR (n=22 312)<br>HR (95% CI); p-value |                                 |  |   |
|--|--|---------------------------------|--|---|
|  | Crude analysis   | Adjusted analysis (drug yes/no) | Adjusted competing risk analysis (drug yes/no) | Adjusted competing risk analysis (drug DDD) |
| Dose missing                                   | 1.24 (0.96 to 1.59);<br>p=0.09                             |                                 |  | 1.21 (0.93 to 1.56);<br>p=0.15              |
| <b>Statins (no dose)</b>                       |  |                                 |  |   |
| <280 DDD                                       | 1.26 (0.88 to 1.81);<br>p=0.20                             |                                 |  | 1.61 (1.12 to 2.33);<br><b>p=0.01</b>       |
| ≥280–370 DDD                                   | 1.16 (0.85 to 1.60);<br>p=0.35                             |                                 |  | 1.59 (1.14 to 2.23);<br><b>p=0.007</b>      |
| >370 DDD                                       | 1.01 (0.64 to 1.59);<br>p=0.97                             |                                 |  | 1.34 (0.84 to 2.15);<br>p=0.22              |
| Dose missing                                   | 0.33 (0.10 to 1.01);<br><b>p=0.05</b>                      |                                 |  | 0.44 (0.14 to 1.36);<br>p=0.15              |
| <b>NSAID cox (no treatment)</b>                |  |                                 |  |   |
| <60 DDD  | 0.96 (0.53 to 1.74);<br>p=0.89                             |                                 |  | 0.97 (0.53 to 1.78);<br>p=0.93              |
| ≥60–280 DDD                                    | 0.51 (0.27 to 0.96);<br><b>p=0.04</b>                      |                                 |  | 0.53 (0.28 to 1.01);<br>p=0.053             |
| >280 DDD                                       | 1.10 (0.56 to 2.13);<br>p=0.79                             |                                 |  | 1.09 (0.56 to 2.12);<br>p=0.80              |
| Dose missing                                   | 1.18 (0.80 to 1.74);<br>p=0.42                             |                                 |  | 1.26 (0.84 to 1.88);<br>p=0.26              |
| <b>Intra-articular steroids (no treatment)</b> |  |                                 |  |   |
| <55 DDD  | 1.18 (0.71 to 1.97);<br>p=0.53                             |                                 |  | 1.14 (0.68 to 1.93);<br>p=0.62              |
| ≥55 DDD  | 2.22 (1.15 to 4.31);<br><b>p=0.02</b>                      |                                 |  | 2.28 (1.14 to 4.54);<br><b>p=0.019</b>      |
| Dose missing                                   | 1.29 (1.01 to 1.66);<br><b>p=0.04</b>                      |                                 |  | 1.30 (1.01 to 1.67);<br><b>p=0.043</b>      |

HR represents number of times to have a revision after 5 years compared with the reference group. A value>1 indicates that the group has higher risk for revision.

Variables included in the final regression model are those with at least one category with a p-value<0.05 for the 10 imputed data sets in a backward selection.

Year index is categorised because the continuous variable violates the proportional-hazards assumption for Cox models on the basis of Schoenfeld residuals.

Bold figures represent results with p values <0.05 in the final regression model

DDD, daily defined dose; NSAIDs, non-steroidal anti-inflammatories; THR, total hip replacement.

of mild diabetes (increased revision risk) and mild liver disease reduced revision risk) were included in the model (online supplemental table C). The effect of large femoral head size (≥44) showed a stronger effect size in this subgroup.

#### Model discrimination

The discriminatory ability of the primary care model using the CPRD-HES data was c-statistic 0.63 for the model with medication use (yes/no) and 0.65 with drug use defined as DDD. In the NJR-HES-PROMs secondary care data set the c-statistic was 0.64.

#### DISCUSSION

The risk of a mid-late revision operation 5 years after primary hip replacement surgery is very low. Within our CPRD GOLD-HES primary data set, we had up to 20 years patient follow-up from the start point of 5 years after the primary operation (so 25 years from the index operation date), and even then, the mid-late revision rate was only 3.1% for THR. The aim of the study was to identify groups of patients with THR that may require follow-up based on their mid-late term revision risk. We found that older age at primary surgery was associated with a lower risk of mid-late term revision; there was an increased risk of

**Table 2** Cox regression model identifying risk factors of revision after 5 years of primary total hip replacement for osteoarthritis: hospital data

| Risk factors (reference category)            | Patients undergoing THR<br>(n=142 275)<br>HR (95% CI); p-value |  |  |
|--|--|--|--|
|  | Crude analysis   | Adjusted analysis                      | Adjusted analysis<br>(competing risk)    |
| Age at primary THR<br>(continuous variable)  | 0.98 (1.0 to 1.0);<br><b>p&lt;0.01</b>                         | 0.97 (0.97 to 0.98); <b>p&lt;0.01</b>  | 0.97 (0.96 to 0.97);<br><b>p&lt;0.01</b> |
| Sex (women)                                  |  |  |  |
| Men  | 1.17 (1.0 to 1.4);<br>p=0.08                                   | 1.22 (1.02 to 1.45);<br><b>p=0.029</b> | 1.17 (0.98 to 1.39); p=0.088             |
| ASA grade (P1-fit and healthy)               |  |  |  |
| P2-Mild disease not incapacitating           | 0.93 (0.7 to 1.2);<br>p=0.52                                   | 0.97 (0.76 to 1.22); p=0.77            | 0.95 (0.75 to 1.21);<br>p=0.70           |
| P3-P5  | 0.70 (0.5 to 1.0);<br><b>p=0.04</b>                            | 0.67 (0.47 to 0.94);<br><b>p=0.022</b> | 0.58 (0.41 to 0.82); <b>p=0.002</b>      |
| Bearing surface (MoP)                        |  |  |  |
| CoC  | 1.08 (0.9 to 1.3);<br>p=0.44                                   | 0.73 (0.56 to 0.94);<br><b>p=0.015</b> | <b>p=0.02</b>                            |
| CoP  | 0.93 (0.7 to 1.2);<br>p=0.57                                   | 0.75 (0.57 to 0.99);<br><b>p=0.039</b> | 0.76 (0.58 to 1.00); <b>p=0.052</b>      |
| CoM-MoC                                      | 2.28 (1.3 to 4.1);<br><b>p=0.01</b>                            | 1.62 (0.87 to 2.99); p=0.13            | 1.65 (0.89 to 3.05); p=0.11              |
| Head size (≤28 mm)                           |  |  |  |
| 32 mm  | 1.28 (1.0 to 1.6);<br><b>p=0.02</b>                            | 1.33 (1.07 to 1.65);<br><b>p=0.012</b> | 1.28 (1.03 to 1.60); <b>p=0.026</b>      |
| 36–42 mm                                     | 1.24 (1.0 to 1.5);<br>p=0.05                                   | 1.21 (0.94 to 1.56); p=0.15            | 1.17 (0.91 to 1.51); p=0.23              |
| ≥44 mm                                       | 3.12 (1.4 to 7.0);<br><b>p=0.01</b>                            | 2.63 (1.12 to 6.19);<br><b>p=0.027</b> | 2.56 (1.09 to 6.02); <b>p=0.031</b>      |
| OHS, 6-month score (0–9 points, worst score) |  |  |  |
| (10–14 points)                               | 0.75 (0.60 to 0.95);<br><b>p=0.02</b>                          | 0.73 (0.58 to 0.91);<br><b>p=0.006</b> | 0.73 (0.58 to 0.92); <b>p=0.007</b>      |
| (15–18 points)                               | 0.66 (0.52 to 0.83);<br><b>p&lt;0.01</b>                       | 0.61 (0.49 to 0.78); <b>p&lt;0.01</b>  | 0.62 (0.49 to 0.79);<br><b>p&lt;0.01</b> |
| (19–23 points)                               | 0.39 (0.29 to 0.53);<br><b>p&lt;0.01</b>                       | 0.36 (0.26 to 0.49); <b>p&lt;0.01</b>  | 0.36 (0.27 to 0.50);<br><b>p&lt;0.01</b> |
| (24–48 points)                               | 0.39 (0.30 to 0.51);<br><b>p&lt;0.01</b>                       | 0.34 (0.26 to 0.45); <b>p&lt;0.01</b>  | 0.35 (0.27 to 0.46);<br><b>p&lt;0.01</b> |

HR represents number of times to have a revision after 5 years compared with the reference group. A value >1 indicates that the group has higher risk for revision.

Variables included in the final regression model are those with at least one category with a p-value <0.05 for a single imputed data set in a backward selection.

Bold figures represent results with p values <0.05 in the final regression model

ASA, American Society of Anaesthesiologists; CoC, ceramic-on-ceramic; CoM - MoC, ceramic-on-metal; CoP, ceramic-on-polyethylene; MoP, metal-on-polyethylene; OHS, Oxford Hip Score; THR, total hip replacement.

revision associated with implant factors (bearing surface and head size) and medication use, and worse pain/function 6 months after the surgery.

Strengths of this study include the use of large, national, routinely collected data sets where the NJR

data are mandatory and have near complete coverage, and the CPRD GOLD data are nationally representative in respect of UK population demographic characteristics. Large sample sizes afforded us the ability to identify predictors of a rare long-term outcome such as revision



surgery. Additional strengths are the detailed surgical and hospital factors available in the NJR data and over 20 years of follow-up in the CPRD-GOLD data set as well as the ability to capture a wide range of primary and hospital factors. A limitation of the NJR-HES-PROMs linked data was limited long-term follow-up—we included only data on primary hip replacement from 2009 onwards (the commencement of PROMs data) up to 2011 to allow for revision rates after 5 years. A further limitation was the inability to define disease severity radiographically although the preoperative pain as measured on OHS (a patient reported assessment) was included within the models. We were also unable to analyse by type of revision as this data were not available in either of our data sets. We acknowledge that changes in anaesthesia and surgical techniques have taken place and current orthopaedic practice may differ. There were also missing data for some of the variables in our data sets and this required us to use imputation to account for this in our analyses.

One of the aims of our study was to understand when revision surgery happens to inform when follow-up should occur. In a previous study using data from the CPRD with over 20 years follow-up, the estimated smoothed hazard plots for hip and knee replacement combined showed consistently higher revision risks for men and younger patients at all timepoints.<sup>23</sup> Other studies have similarly shown that the risk of revision after THR is higher for younger patients.<sup>24 25</sup> Our finding in respect of age is consistent with this existing literature.

In our analysis of other patient factors, those who were current smokers (time of primary surgery) were at reduced risk of mid-late term revision.<sup>26 26</sup> Kapadia *et al* found an increased risk of revision in the early years for this group of patients; our emphasis on mid-late revision may be an explanation for this difference if there has been a higher frequency of early revision in this group. Similarly, other authors have found increased risk of early revision for patients with higher ASA grades at primary surgery,<sup>27</sup> whereas our results indicate reduced risk at mid-late revision, which may be related to a state of poorer general health. Fractures in the pelvis, proximal/humerus, wrist/forearm, spine or rib may be indicative of fragility, which are also known to increase risk of early revision;<sup>28</sup> patients without a history of these conditions may be at increased risk of mid-late term revision due to longevity. Other findings were a fourfold increased revision risk associated with malabsorption, but it is very rare with only 0.3% of patients having this comorbidity. Over 30% of patients had hypertension preoperatively, but it is unclear why this in itself would confer lower revision risk and we propose it is simply an association.

The OHS records pain and function and it has been found that a poor 6-month postoperative score reliably predicts the 5-year outcome trajectory for pain and function.<sup>29</sup> Our finding of an increased risk of mid-late revision associated with poorer scores 6 months after primary surgery is consistent with this trajectory and early

identification of this group for targeted follow-up may be appropriate.

These findings require further investigation. Postoperative statin use has previously been suggested to reduce revision risk for hip replacement,<sup>30</sup> whereas the association seen here in our study on mid-late revision suggested an increased revision risk. Also, our study found an association between antidepressant use prior to primary surgery and increased risk of revision; however, we did not find that patient levels of anxiety and depression recorded in preoperative PROMS were a risk factor. In another study of hip and knee replacement, use of antidepressant medication preoperatively did not affect outcomes 1 year post-surgery,<sup>31</sup> but the effect on mid-late term revision was not discussed.

The use of intra-articular glucocorticoid steroid injections in 17% of the population was associated with a twofold increased risk of mid-late term revision following THR, which is the opposite of our finding following oral glucocorticosteroid prior to knee replacement (HR: 0.72 (95% CI: 0.53 to 0.99) (in press). Although the administration of the injected steroid was linked to the index hip, our data did not allow us to identify site of administration of this injection. We postulate the increased risk of infection following intra-articular injection of steroid and subsequent revision,<sup>32</sup> but cannot demonstrate this association from our study.

The MoP bearing surface was most commonly used (66% of patients) in the NJR data set over the time period studied. The bearing surfaces with a lower risk were the 20% of CoC patients, and 13% of CoP patients which is consistent with the non-inferiority shown in the network meta-analysis conducted by Lopez-Lopez *et al*.<sup>33</sup> Prior to analysis we had excluded patients who had hip resurfacing and metal-on-metal hip replacement, where larger head sizes are common, as we know revision risk is higher. However, we still observed an association where, in the remaining THR patients, a larger head size was associated with higher mid-late revision risks. In the 17th NJR annual report,<sup>2</sup> the associations of head size and bearing surface were examined for THR revision rates and reflect earlier work by Smith *et al*.<sup>34</sup> With MoP and CoP, large head sizes appear to be associated with higher failure rates particularly with 36mm heads used with cemented fixation and heads >36mm used with hybrid and uncemented fixation. In our study here, we also observe large head size as being associated with revision risk. Of concern is that, according to the 17th NJR report, in 2003, the vast majority of hip replacements utilised heads of 28mm or smaller across all fixation methods but since 2003, there has been a progressive shift away from small heads in cemented hip replacements to larger head sizes (>28mm) with alternative fixation methods (uncemented or hybrid). In respect of bearing surface, NJR Kaplan-Meier plots of revision rates also show lower revision risk for CoC and CoP bearing surfaces.<sup>2</sup> These implant factors are hence potentially relevant for making decisions about which patient groups to target for extended follow-up.

This is one of the first studies to specifically identify predictors of mid-late term revision risk for hip replacement surgery. It is clear that the risk factors we identified for hip replacement are different to those for knee replacement and suggests the need for different models of organisation of any follow-up. For THR, implant factors of bearing surface and head size, and 6-month postoperative pain and function scores, appear to be important and relevant factors in deciding which patients may require extended follow-up. Further work is needed to explore the associations with prescription medications observed in our data. In conclusion, we suggest that this analysis of routinely collected NHS data provides useful insights to consider in the design of any future hip arthroplasty follow-up.

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**Data sharing statement** Access to data is available from the National Joint Registry for England and Wales, Northern Ireland and the Isle of Man, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data access applications can be made to the National Joint Registry Research Committee. Access to linked HES and PROMS data is available through data applications to NHS Digital.

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