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HIP

The risk of cardiac failure following metal-on-metal hip arthroplasty

S. A. Sabah,
J. C. Moon,
S. Jenkins-Jones,
C. I. Morgan,
C. J. Currie,
J. M. Wilkinson,
M. Porter,
G. Captur,
J. Henckel,
N. Chaturvedi,
P. Kay,
J. A. Skinner,
A. H. Hart,
C. Manisty

From University College London, United Kingdom

Aims
The aim of this study was to determine whether patients with metal-on-metal (MoM) arthroplasties of the hip have an increased risk of cardiac failure compared with those with alternative types of arthroplasties (non-MoM).

Patients and Methods
A linkage study between the National Joint Registry, Hospital Episodes Statistics and records of the Office for National Statistics on deaths was undertaken. Patients who underwent elective total hip arthroplasty between January 2003 and December 2014 with no past history of cardiac failure were included and stratified as having either a MoM (n = 53 529) or a non-MoM (n = 482 247) arthroplasty. The primary outcome measure was the time to an admission to hospital for cardiac failure or death. Analysis was carried out using data from all patients and from those matched by propensity score.

Results
The risk of cardiac failure was lower in the MoM cohort compared with the non-MoM cohort (adjusted hazard ratio (aHR) 0.901; 95% confidence interval (CI) 0.853 to 0.953). The risk of cardiac failure was similar following matching (aHR 0.909; 95% CI 0.838 to 0.987) and the findings were consistent in subgroup analysis.

Conclusion
The risk of cardiac failure following total hip arthroplasty was not increased in those in whom MoM implants were used, compared with those in whom other types of prostheses were used, in the first seven years after surgery.

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Metal-on-metal (MoM) prostheses of the hip have been widely used,1 but are now known to have unacceptably high rates of failure.2–4 This has triggered regulatory alerts, device recalls and mandatory surveillance programs. The failure of these devices has led to many patients subsequently undergoing early revision.5–8 Corrosion and wear of MoM implants, which are composed of cobalt-chromium alloy, can result in the release of particulate debris and metal ions into the circulation. Alongside localized effects, MoM prostheses have been associated with systemic complications such as cardiotoxicity and mortality.9–14 Concerns have been recently raised about cobalt cardiomyopathy, particularly following the report of a three-fold increased risk in hospital admissions due to cardiac failure in a subgroup of men with MoM prostheses.15,16 The findings have, however, been inconsistent.13,17,18 The symptoms and signs of cardiac failure are common in patients undergoing total hip arthroplasty (THA) and any association between the type of prosthesis and cardiac failure presenting at a later date, and usually to a different clinician, could easily be overlooked.19

Record-linkage studies have been used to investigate the relationship between death due to cancer in patients who have undergone MoM THA, concluding that there is no increased risk.20–22 In this study, we tested the hypothesis that MoM THA was associated with increased risk of cardiac failure compared with other types of prostheses.

Patients and Methods
This was a retrospective cohort study using linked national data sets. The United Kingdom National Joint Registry (NJR), which is the largest arthroplasty registry in the world,23

was the primary source of data for this study. The submission of data to the registry has been mandatory for National Health Service (NHS) hospitals in England, Wales and Northern Ireland since 1 April 2011, with > 95% of primary procedures captured in 2015 and now with information from more than two million arthroplasties.²³

Each record describes the demographics of the patient including age, gender, American Society of Anesthesiologists (ASA) grade,²⁴ body mass index (BMI), the type of prosthesis including the bearing surface, size of the components and brand and surgical details. Corresponding data are generated routinely for NHS Hospital Episodes Statistics (HES),²⁵ which specify the reasons for admission, procedures performed and length of stay. The Office for National Statistics (ONS)²⁶ records death certification data on all deaths registered in England and Wales including the date and cause(s) of death.

Individual patient-level record linkage was carried out by NHS Digital (NHS, Leeds, United Kingdom), using the NHS number, date of birth, gender and postcode. Only patients consenting to inclusion in the NJR registry and to the use of their data for research purposes were included. Pseudo-anonymous data from the NJR were provided to the investigators for analysis. The study was undertaken in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) checklist.²⁷

The inclusion criteria involved those who underwent elective, primary THA between 1 January 2003 and 31 December 2014 who had linked HES records. This provided a minimum period of six preoperative years in which to establish a record of cardiac failure at the time of THA and a minimum postoperative follow-up of six months. Patients with cardiac failure prior to or in the six months following THA, which would most likely have been attributable to pre-existing disease, were excluded from the overall analysis but included in sensitivity analyses. A step-wise process was used to remove records of insufficient quality and cases with duplicate or conflicting data. The exposure process was used to remove records of insufficient quality for all analysis but included in sensitivity analyses. A step-wise process was used to remove records of insufficient quality. The time at risk was the primary outcome measure for this study. The secondary outcome measure was all causes of mortality. The time at risk for the outcome was measured from the day of the arthroplasty until the first hospital admission with cardiac failure, death or the end of the study period (March 2015). Cardiac failure was defined by the appropriate diagnostic codes following discharge from hospital or on a death certificate (see supplementary material). The demographics of the patients and details of the operation were extracted from NJR and comorbidities were extracted from HES data.

The study protocol was approved by the Research Subcommittee of the NJR and the Data Access Advisory Group of NHS Digital.

**Statistical analysis.** Cox proportional hazards models were used to estimate the hazard ratio (HR) for primary and secondary outcomes by group and were adjusted for potential confounding factors including age at the time of the operation, gender, a history of type 2 diabetes, hypertension, coronary heart disease and other indicators of comorbidity and frailty (Charlson comorbidity index,²⁸ ASA grade and the number and length of hospital admissions in the five years prior to arthroplasty).

In order to control for the indications available in the data set, propensity-matched analyses (adjusted and unadjusted) were performed using one-to-one matching of patients undergoing MoM arthroplasty with those undergoing a non-MoM arthroplasty. The cohort was stratified by gender before propensity matching and matched by age, history of diabetes, heart disease and hypertension, Charlson index and ASA class. A caliper of 0.2 was used for the propensity score.

Further comparisons were performed for subgroups, including those at the highest risk of cardiac failure and those at the highest risk of implant failure,²⁹ including those with an Articular Surface Replacement (ASR) XL Acetabular System (DePuy Orthopaedics, Warsaw, Indiana). BMI was available for approximately half of the patients (n = 278 757) and was included as a further covariate for this subset. Data processing was performed using Microsoft SQL Server 2012 (Redmond, Washington), and statistical analyses with SPSS Statistics version 22.0 (IBM, Armonk, New York). The proportional hazards assumption was tested using the correlation between survival and partial residuals.

**Results**

A total of 581 954 patients with a THA recorded in the NJR could be linked to HES and ONS data. Following data cleaning and the exclusion of emergency admissions, 550 589 (94.6%) THAs remained. Of these, 535 776 (97.3%) had no history of cardiac failure either before their arthroplasty or within the subsequent six months. This cohort was used in the main analysis (Fig. 1). A total of 53 529 patients (10.0%) had a MoM hip arthroplasty and were matched in the propensity analysis. Notably, the patients were younger (mean age: 58.6 years, SD 11.1) versus 69.2 years, SD 11.0). More were male (61.1% versus 38.1%) with fewer comorbidities, as measured by the prevalence of diabetes, coronary heart disease and hypertension, Charlson index and ASA grade (Table I). By design, propensity matching reduced these differences (Table I).

There were 1431 incidents of cardiac failure in the MoM cohort and 21 245 in the non-MoM cohort. The crude event rates were 3.8 and 9.7 per 1 000 person years’ exposure, respectively, with a crude relative rate of 0.389 (95% confidence interval (CI) 0.368 to 0.410, Table II). Following adjustment, the adjusted hazard ratio (aHR) for the MoM cohort relative to the non-MoM cohort was 0.901.⁴
incidents of cardiac failure in the MoM cohort and 1004 in
the non-MoM cohort. Due to the longer follow-up, the
incidence of cardiac failure with increasing age, ranging from
0.600 (0.353 to 1.019) in the youngest cohort (≤44 years) to
1.15 (0.908 to 1.370) in the oldest (>85 years).

In the propensity-matched analysis, there were 1431
incidents of cardiac failure in the MoM cohort and 1004 in
the non-MoM cohort. Due to the longer follow-up, the
crude event rates were lower in the MoM cohort (3.8 events
per 1000 person years versus 4.1 events per 1000 person
years), with an unadjusted relative rate of 0.917 (95% CI
0.846 to 0.994, Table II). In adjusted analyses, the aHR was
0.909 (95% CI 0.838 to 0.987, Table III). For all-cause
mortality, the aHR was 0.877 (95% CI 0.835 to 0.922,
Table III). The subgroup analysis of the propensity-
matched cohorts is illustrated in Figure 3. No subgroup had
a significantly increased aHR.

A total of 557 patients in the MoM cohort and 14 256 in
the non-MoM cohort had a previous history of cardiac failure.
The respective event rates for the first subsequent
admission with cardiac failure were 136.6 and 195.3 per
1000 person years (Table IV). After adjustment, the aHRs
for cardiac failure and all-cause mortality were 0.997 (95%
CI 0.885 to 1.122; p = 0.952) and 0.983 (95% CI 0.854 to
1.132; p = 0.814), respectively. In the analysis that included
BMI as a covariate, the aHRs for cardiac failure and all-
cause mortality were 0.997 (95% CI 0.885 to 1.122; p = 0.952)
and 0.983 (95% CI 0.854 to 1.132; p = 0.814), respectively.

Additional analyses were performed on the MoM cohort
by the type of device including the type of head, the brand
of the acetabular component and the size of the compo-
ments. For patients receiving a modular head, the aHR
approximated unity (aHR = 1.013; 95% CI 0.953 to
1.078). Of these patients, the aHR for those receiving an
ASR XL prosthesis was 0.970 (95% CI 0.776 to 1.213).
For those having a resurfacing, the aHR was significantly
lower (0.656; 95% CI 0.587 to 0.732, Table V). No brand of
acetabular component or size of femoral head had an
increased aHR for cardiac failure (supplementary fig a).

Discussion
In this study involving more than half a million patients
with arthroplasties of the hip, there was no association
between a MoM arthroplasty and an increased incidence of
cardiac failure in the first seven years after surgery.
In contrast to the recent report of increased rates of admission with cardiac failure in subgroups of patients with MoM arthroplasties, the risk of cardiac failure in these patients appeared to be lower than those with other types of bearing surfaces. These findings persisted after extensive adjustment for confounding factors, after matching by propensity score and even among patients at the highest risk of either cardiac failure or implant failure. Patients with pre-existing cardiac failure had, as expected, significantly higher rates of admission with cardiac failure and death due to cardiac failure. However, this was not influenced by exposure to MoM arthroplasty. In common with other studies, we found no increase in all-causes of mortality with MoM arthroplasty.

It is however, likely that there are residual confounding factors for which we have failed to account. Our finding that the lower rate for all causes of mortality from MoM arthroplasties was markedly attenuated by multivariate adjustment and matching by propensity score, indicates that this is likely to be due to lower morbidity. These results are in line with previously published studies assessing the risk of cancer and mortality with these patients, in which similarly lower HRs were reported, particularly in patients with a MoM resurfacing. Resurfacing is a bone-conserving option, sought by patients aiming to return to high levels of function. Aspects of better health which are not captured in these data such as exercise and not smoking or socioeconomic status may explain these findings.

Fig. 1
Flowchart showing data linkage, data cleaning and selection of the cohorts. NJR, National Joint Registry; NHS, National Health Service; HES, hospital episode statistics, MoM, metal-on-metal
variations in anatomy and other factors that may be associated with a poorer outcome. These patients therefore have more in common with those undergoing non-MoM arthroplasty than those undergoing a resurfacing. This is reflected in our findings, in which the HR for cardiac failure in patients undergoing a modular MoM arthroplasty was close to unity, and thus higher than in those undergoing a resurfacing.

**Table II.** Incidents, the rate of events and the crude relative risk of heart failure and all-cause mortality for patients with metal-on-metal and non-metal-on-metal arthroplasties: all patients and those matched by propensity score.

<table>
<thead>
<tr>
<th></th>
<th>MoM Patients</th>
<th>MoM Events</th>
<th>MoM Rate</th>
<th>MoM Non-MoM</th>
<th>Non-MoM Events</th>
<th>Non-MoM Rate</th>
<th>Crude relative risk (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>53,529</td>
<td>1,431</td>
<td>3.8</td>
<td>482,247</td>
<td>21,245</td>
<td>9.7</td>
<td>0.389 (0.368 to 0.410)</td>
</tr>
<tr>
<td>Cardiac failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propensity-matched patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>53,529</td>
<td>1,431</td>
<td>3.8</td>
<td>53,529</td>
<td>1,004</td>
<td>4.1</td>
<td>0.917 (0.846 to 0.994)</td>
</tr>
<tr>
<td>Death</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Rate per 1000 person years’ exposure
MoM, metal-on-metal; CI, confidence interval

**Table III.** Adjusted hazard ratio of cardiac failure and all-cause mortality for patients with metal-on-metal and non-metal-on-metal arthroplasties: all patients and those matched by propensity score.

<table>
<thead>
<tr>
<th></th>
<th>Adjusted hazard ratio (95% CI)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>0.901 (0.853 to 0.953)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Death</td>
<td>0.892 (0.862 to 0.924)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Propensity-matched patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>0.909 (0.838 to 0.987)</td>
<td>0.023</td>
</tr>
<tr>
<td>Death</td>
<td>0.877 (0.835 to 0.922)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Cox PH model
CI, confidence interval

Fig. 2

Adjusted hazard ratio (aHR) of cardiac failure for patients with metal-on-metal (MoM) and non-MoM arthroplasties: all patients by subgroup. CI, confidence interval; CHD, coronary heart disease; BMI, body mass index; ASA, American Society of Anesthesiologists grade.
MoM arthroplasties vary both in design and manufacturing process, and have different rates of failure and circulating levels of metal ions. Subgroup analysis by manufacturer found no differences between devices associated with high rates of implant failure such as stemmed implants, those with a large femoral head and brands including the ASR XL and other MoM implants. The ASR XL (DePuy) is a type of large-diameter, stemmed arthroplasty with a high rate of implant failure. It was subject to a worldwide device recall and was recently identified as being associated with an increased risk of cardiac failure in elderly men.

Cobalt cardiomyopathy was first described in 1967 in patients with excess dietary cobalt, ‘Quebec beer-drinkers’ cardiomyopathy’. More recently, case reports and small series have reported cardiomyopathy related to failure of MoM implants. However, there were < 30 cases in total and these patients had extreme levels of circulating metal ions. Prentice et al performed a cross-sectional observational study of systemic complications and found a 5% lower ejection fraction in 35 patients with MoM resurfacing implants compared with patients with conventional arthroplasties. Subsequent multimodality work using both echocardiography and MRI, the benchmark measure of cardiac function, failed to replicate these findings despite including patients with high levels of metal ions in the blood (mean cobalt 30 ppb (range 8 to 118). Using epidemiological approaches, one study found lower standardized mortality ratios for cardiovascular death in a large cohort of patients with a MoM arthroplasty compared with those with a non-MoM arthroplasty. Cardiac failure was not specifically studied. A recent report from Australia

### Table IV

<table>
<thead>
<tr>
<th></th>
<th>MoM Patients</th>
<th>Events</th>
<th>Rate</th>
<th>Non-MoM Patients</th>
<th>Events</th>
<th>Rate</th>
<th>Adjusted hazard ratio (95% CI)</th>
<th>p-value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac failure</td>
<td>557</td>
<td>293</td>
<td>136.6</td>
<td>14 256</td>
<td>6747</td>
<td>195.3</td>
<td>0.977 (0.885 to 1.122)</td>
<td>0.952</td>
</tr>
<tr>
<td>Death, n</td>
<td>557</td>
<td>208</td>
<td>64.6</td>
<td>14 256</td>
<td>4933</td>
<td>96.0</td>
<td>0.983 (0.854 to 1.132)</td>
<td>0.814</td>
</tr>
</tbody>
</table>

*rate per 1000 person years’ exposure
†Cox PH model
MoM, metal-on-metal; Cl, confidence interval
noted a three-fold increase in the risk of admissions to hospital because of cardiac failure in 63 men with an ASR XL THA with a mean age of 82 years, compared with 1502 men with a metal-on-plastic THA. These patients were significantly different from our patients, both in age and risk of cardiac failure. All patients in their study had a high rate of cardiac failure; the incidence of cardiac failure in the control group was 18% at a mean of 7.2 years, and the effect was confined to men. In our study, there was no increased risk of cardiac failure in older patients with an ASR XL THA (supplementary table ii). The numbers were small (n = 786), with wide CIs.

This study is the largest epidemiological study of systemic effects (cardiac failure) after MoM arthroplasty. Given the nature of the sources of the data, case recruitment should be comprehensive and the findings can therefore be generally followed. The statistical power of the dataset enabled extensive subgroup analysis to address specific concerns such as the differences between gender and brands. We accept that before 2005, the data in the NJR include less than 80% of the arthroplasties undertaken in the United Kingdom and some MoM arthroplasties may have been omitted from the analysis.

Limitations include those of the HES data, where coding is not performed by clinicians and the coding of cardiac failure is imperfect, although this should introduce only analytical noise, rather than bias. Cardiac failure is mainly captured when severe, as in admission to hospital or death, missing noise, rather than bias. Cardiac failure is mainly captured when severe, as in admission to hospital or death, missing when severe, as in admission to hospital or death, not being performed by clinicians and the coding of cardiac failure for our patients, all patients in their study had a high rate of cardiac failure; the incidence of cardiac failure in the control group was 18% at a mean of 7.2 years, and the effect was confined to men. In our study, there was no increased risk of cardiac failure in older patients with an ASR XL THA (supplementary table ii). The numbers were small (n = 786), with wide CIs.

In conclusion, we found a lower incidence of cardiac failure and mortality in patients with MoM arthroplasties compared with other types of arthroplasty of the hip in the first seven years after surgery. While there may be confounding factors by indication, these results should provide reassurance to clinicians and patients alike, regarding the cardiac sequelae associated with these devices. We recommend epidemiological analysis at five-yearly intervals to investigate for any latent effects.

Take home message:
Patients with metal-on-metal hip prostheses (of any type) are not at significantly increased risk of severe heart failure in the first 7 years after elective surgery.

Supplementary material
Further information including tables and figures are available alongside the online version of this article at www.bjj.boneandjoint.org.uk

Table V, Incidents, the rate of events and adjusted hazard ratio of cardiac failure for patients with either modular or resurfaced metal-on-metal and non-metal-on-metal arthroplasties

<table>
<thead>
<tr>
<th></th>
<th>Patients</th>
<th>Events</th>
<th>Event rate*</th>
<th>Adjusted hazard ratio (95% CI)</th>
<th>p-value†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modular</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>25 656</td>
<td>1084</td>
<td>6.1</td>
<td>1.013 (0.953 to 1.078)</td>
<td>0.675</td>
</tr>
<tr>
<td>Controls</td>
<td>482 247</td>
<td>21 245</td>
<td>9.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASR XL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases</td>
<td>2353</td>
<td>78</td>
<td>4.5</td>
<td>0.970 (0.776 to 1.213)</td>
<td>0.790</td>
</tr>
<tr>
<td>Controls</td>
<td>482 247</td>
<td>21 245</td>
<td>9.6</td>
<td></td>
<td></td>
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<tr>
<td>Resurfaced</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Cases</td>
<td>27 870</td>
<td>347</td>
<td>1.7</td>
<td>0.656 (0.587 to 0.732) &lt; 0.001</td>
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</tr>
<tr>
<td>Controls</td>
<td>482 247</td>
<td>21 245</td>
<td>9.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*rate per 1000 person years’ exposure
†Cox PH model
CI, confidence interval

References
Null