■ HIP

Association between surgeon and hospital volume and outcome of first-time revision hip arthroplasty for aseptic loosening

A PROSPECTIVE OBSERVATIONAL COHORT STUDY USING THE NATIONAL JOINT REGISTRY DATASET

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Aims

This study evaluates the association between consultant and hospital volume and the risk of re-revision and 90-day mortality following first-time revision of primary hip arthroplasty for aseptic loosening.

Methods

We conducted a cohort study of first-time, single-stage revision hip arthroplasties (RHAs) performed for aseptic loosening and recorded in the National Joint Registry (NJR) data for England, Wales, Northern Ireland, and the Isle of Man between 2003 and 2019. Patient identifiers were used to link records to national mortality data, and to NJR data to identify subsequent re-revision procedures. Multivariable Cox proportional hazard models with restricted cubic splines were used to define associations between volume and outcome.

Results

Among 12,961 RHAs there were 513 re-revisions within two years, and 95 deaths within 90 days of surgery. The risk of re-revision was highest for a consultant's first RHA (hazard ratio (HR) 1.56 (95% CI 1.15 to 2.12)) and remained significantly elevated for their first 24 cases (HR 1.26 (95% CI 1.00 to 1.58)). Annual consultant volumes of five/year were associated with an almost 30% greater risk of re-revision (HR 1.28 (95% CI 1.00 to 1.64)) and 80% greater risk of 90-day mortality (HR 1.81 (95% CI 1.02 to 3.21)) compared to volumes of 20/year. RHAs performed at hospitals which had cumulatively undertaken fewer than 167 RHAs were at up to 70% greater risk of re-revision (HR 1.70 (95% CI 1.12 to 2.59)), and those having undertaken fewer than 307 RHAs were at up to three times greater risk of 90-day mortality (HR 3.05 (95% CI 1.19 to 7.82)).

Conclusion

This study found a significantly higher risk of re-revision and early postoperative mortality following first-time single-stage RHA for aseptic loosening when performed by lower-volume consultants and at lower-volume institutions, supporting the move towards the centralization of such cases towards higher-volume units and surgeons.

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Introduction

Primary hip arthroplasty (PHA) is a well-established treatment for arthritis, associated with excellent outcomes, and can be anticipated to last up to 25 years in 58% of patients.[1,2] Some patients (up to 5% at ten years) may require revision surgery, such as when the components become loose or unstable, infection develops, or the bone supporting the implant fractures. Revision hip arthroplasty (RHA) is more expensive, technically demanding, and associated with a higher risk of postoperative complications compared to PHA.[3-5]

Centralization of specialist services has led to measurable and sustained improvements in patient outcomes, supporting efforts to expand this model to surgical practice. There is substantial variation in surgeon experience of RHA nationally,[6] and in England the Getting It Right First Time

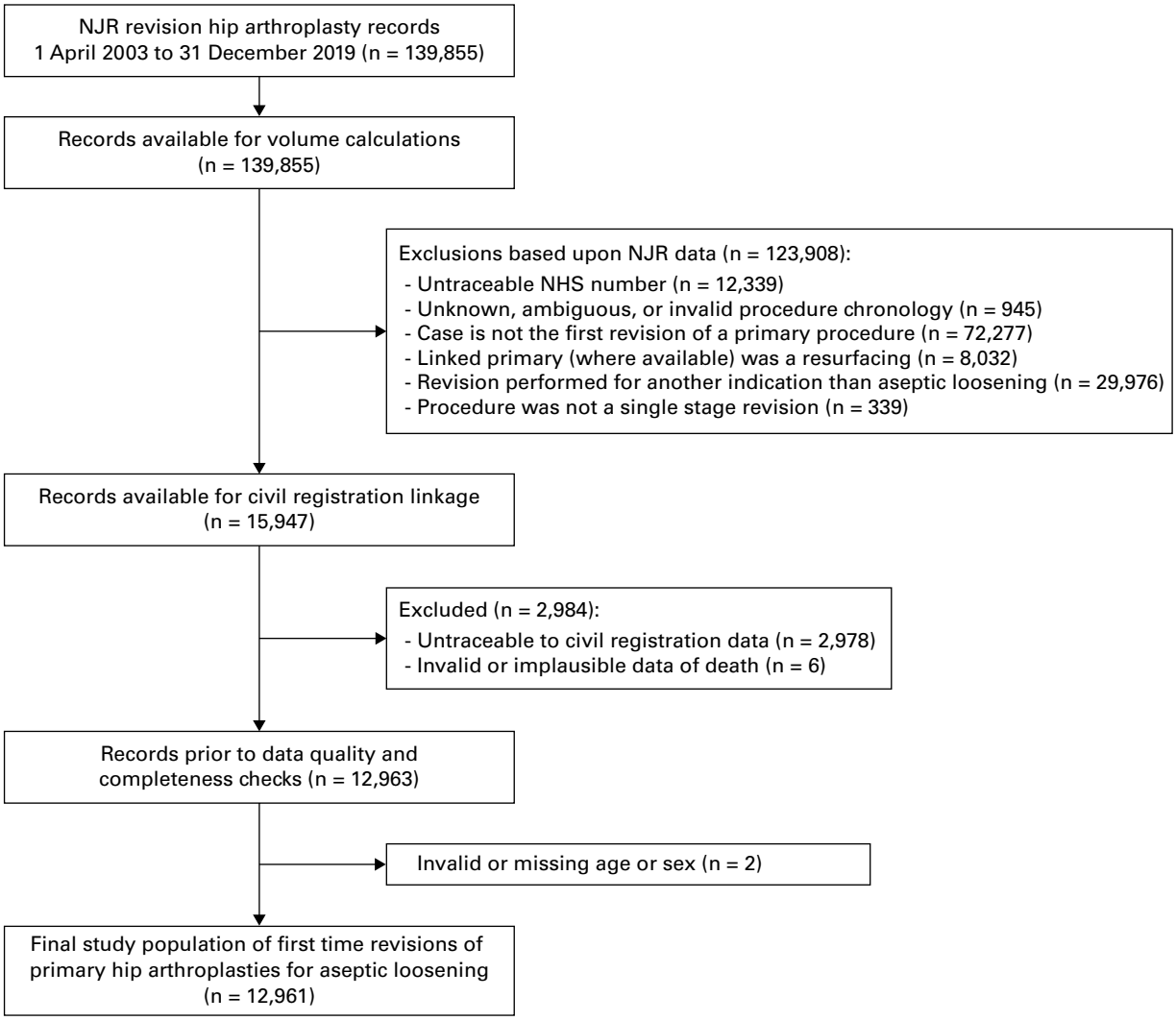

Fig. 1

Study flow diagram. NJR, National Joint Registry.

(GIRFT) programme has identified revision arthroplasty as an area in which patient outcomes and health service costs may particularly benefit from concentrating clinical expertise and resources.[7,8] These efforts have been substantiated by previous retrospective studies showing higher early (90-day) mortality and reoperation rates in association with lower consultant and hospital surgical volumes.[9,10]

The aim of this study was to use data from the National Joint Registry (NJR), collected from England, Wales, Northern Ireland, and the Isle of Man, to evaluate any association between consultant and centre (hospital) volume of RHAs and the risk of re-revision or early postoperative mortality following first-time RHAs performed for aseptic loosening.

Methods

Approval for this population cohort study was granted by the UK Healthcare Quality Improvement Partnership (reference HQIP-360). We received data for all RHAs recorded in the NJR between 1 April 2003 and 31 December 2019. Submission to the NJR has been mandatory for independent healthcare organizations since April 2003 and for NHS organizations since April 2011. The dataset included unique identifiers for the responsible consultant surgeon and healthcare organization (centre) where the procedure was performed to enable volume calculations.

NJR RHA records were received prelinked to the preceding PHA procedure (where this was captured by the NJR) and, where cases were linked to a record in Hospital Episode Statistics (HES) at any point, to civil registration mortality data (provided by the Office for National Statistics) to capture mortality outcomes.[11,12]

All consented RHA procedures submitted to the registry were eligible for inclusion (Figure 1). Surgeon and centre volume calculations were then made for each individual case. Records were then filtered to exclude cases with missing patient identifiers or ambiguous procedure chronology and to include only cases that were performed as the first-time revision of a

Table I. Study cohort characteristics.

Variable	Total
Revisions, n	12,961
Mean age, yrs (SD)	73 (11)
Sex n (%)	
Female	7,063 (54.5)
Male	5,898 (45.5)
Mean BMI, kg/m² (SD)*	28.8 (5.2)
ASA grade n (%)	
I	911 (7.0)
II	7,808 (60.2)
≥ III	4,242 (32.7)
Practice setting, n (%)	
NHS provider	12,023 (92.8)
Independent provider	938 (7.2)
Components replaced at revision, n (%)	
Acetabular and femoral	6,916 (53.4)
Acetabular only	3,975 (30.7)
Femoral only	1,806 (13.9)
Head and/or liner only	250 (1.9)
No components replaced	14 (0.11)
Bone graft use at revision, n (%)	
Acetabular bone grafting	3,211 (24.8)
Femoral bone grafting	296 (2.3)
Acetabular and femoral bone grafting	408 (3.1)
No bone grafting	9,046 (69.8)
Surgeon grade, n (%)	
Consultant assisted by non-consultant	11,530 (89.0)
Consultant assisted by consultant	455 (3.5)
Non-consultant assisted by consultant	729 (5.6)
Non-consultant assisted by non-consultant	247 (1.9)
Intraoperative complication, n (%)	
No	12,519 (96.6)
Yes	442 (3.4)

*Data from 9,355 patients (72.2%).
ASA, American Society of Anesthesiologists.

PHA; this was determined either by the case being directly linkable in the NJR to a preceding PHA which was the last recorded procedure on the same side in the same individual, or by the record being explicitly labelled as the first-time revision of PHA. We additionally excluded any case where the linked primary procedure was a resurfacing hip arthroplasty. Records were categorized hierarchically based on the indication for the revision procedure: 'infection', 'trauma', 'dislocation', 'adverse reaction to metal debris (ARMD)', 'aseptic loosening' (including lysis), and 'other aseptic' (any noninfected indication not captured by the other groups). Only cases performed for aseptic loosening were included in the study cohort. Finally, we excluded cases that were not recorded as a single-stage revision (i.e. a single procedure providing definitive treatment) such that any subsequent revision procedures could be considered 'unplanned'. The cleaned NJR data were then linked to available civil registration data.

Main exposures. Our principal exposures were the annual and cumulative RHA volume of the responsible consultant and treating centre which were derived uniquely for each case, capturing changes in consultant and centre volume which vary with time. We derived annual and cumulative RHA volumes in totality for all revision indications and prior to exclusions, rather than exclusively for RHA performed for aseptic loosening. Thus, for each first-time revision for aseptic loosening case in the study cohort, we determined two metrics: the number of RHA cases (of any indication) recorded by the responsible consultant and host centre in the 365 days before the index case; and the total cumulative volume of all NJR-recorded RHAs previously undertaken by the consultant and centre before the day the index case was undertaken and since the inception of NJR data collection.

Outcome. The date of the first of any subsequent re-revision procedures captured by the NJR prior to 30 March 2020 (the date that outcome data were end-censored) for each RHA record was determined, along with the date of death (if it occurred) to establish and censor both implant and mortality-specific survival time relative to the date of index surgery. For mortality analyses, we considered only deaths occurring within the first 90 days postoperatively.

Patient and surgical characteristics. Available NJR variables included age, sex, BMI, American Society of Anesthesiologists (ASA) grade,[13] and the practice setting (NHS or independent/private). Surgical characteristics included data on which implant components were replaced at the revision procedure, the use of bone graft, the grade of the lead (operating) and assistant surgeon, and whether there was an intraoperative complication noted during the procedure.

We identified 12,961 first-time revisions of PHA for aseptic loosening (12,676 patients) after linkage and exclusions (Figure 1). Procedures were drawn from 950 unique consultant surgeons and 137 healthcare organizations, including a total of 45,485 years of follow-up time (median case follow-up time 3.14 years). Characteristics of the study population are shown in Table I.

Statistical analysis. To explore how case-mix characteristics varied with volume, the volume distribution was split to analyze any patterns that may exist, particularly at the margins. Multivariable Cox proportional hazard models were used to investigate the relationship between volume and outcome, adjusting for age, sex, ASA grade, and practice setting. Volume was modelled as a continuous variable using restricted cubic splines to explore and characterize any non-linear relationships or threshold effects. Knots were pre-specified using the fifth, 27.5th, 50th, 72.5th, and 95th centiles of the volume distribution. To preserve statistical power, we performed separate models for each combination of consultant and centre, and annual and cumulative volume. For the small number of patients in the study cohort who underwent bilateral RHA, each procedure was considered an independent event.

The proportional hazards assumptions for the main exposure were assessed formally and visually inspected using smoothed Schoenfeld residual plots. Evidence of departure from time proportionality was observed for both consultant and centre volume and the risk of re-revision (Supplementary Material), with the risk of re-revision within the first two years differing significantly compared to later follow-up periods. Therefore, we present models for re-revision within two years as our primary analysis with models for all timepoints detailed in the Supplementary Material. We performed a sensitivity analysis,

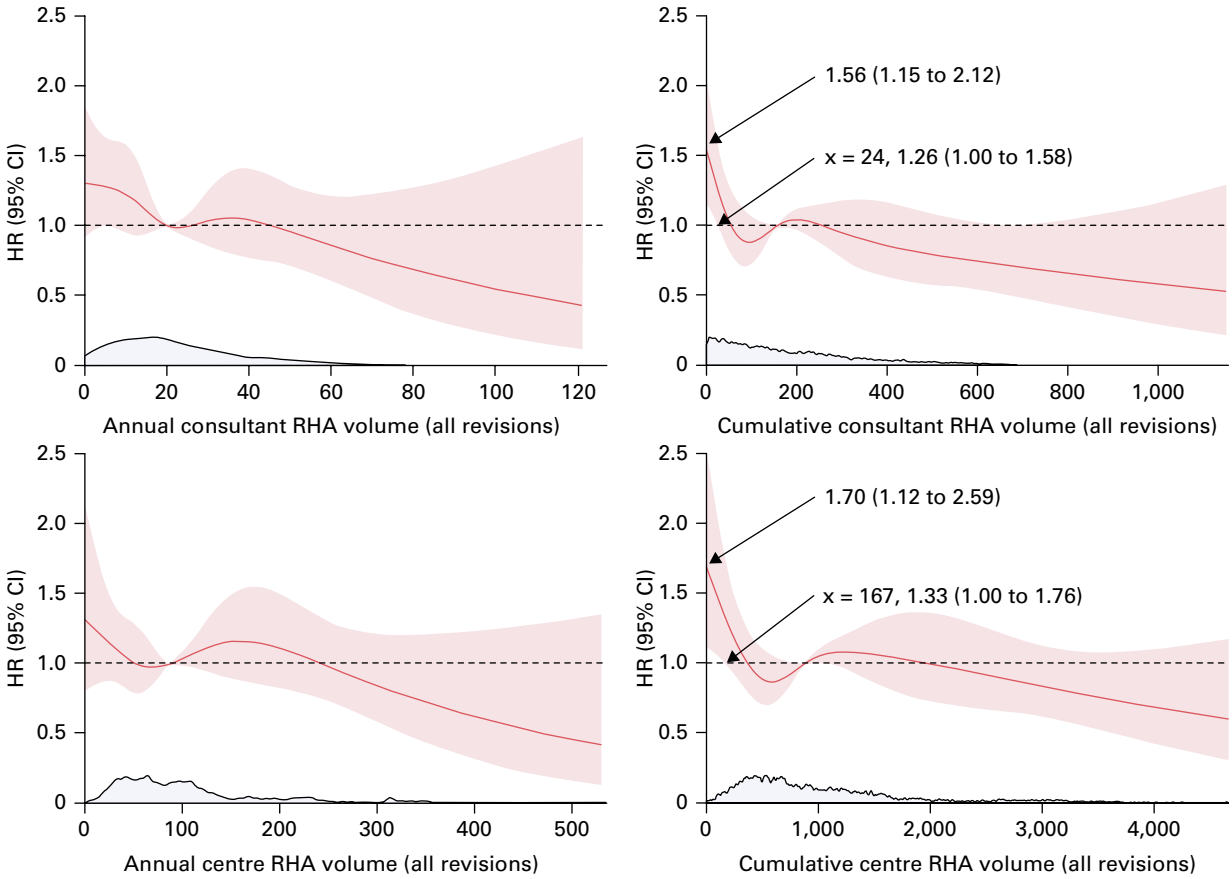

Fig. 2

Plot matrix showing the marginal association of change in surgical volume on the risk of all-cause revision (within two years) following first-time revision hip arthroplasty (RHA) for aseptic loosening after adjustment for confounding factors. Shaded areas represent 95% CIs which converge where the spline is centred (referenced) at the median volume. The grey rug-plot immediately adjacent to the x-axis shows the density distribution of observations upon which the model is based. The annotation indicates (where relevant) the x-axis volume value corresponding to the intersection of the lower 95% CI and a HR of one, highlighting the range of volume where risk is significantly elevated. Coefficients for adjustment variables along with full details of the Cox proportional hazard model fit characteristics are presented in the Supplementary Material.

modelling the relationship between annual consultant volume and outcomes conditional upon the responsible consultant having already reached a cumulative threshold volume which was chosen based on the findings of our primary analysis. Where presented, modelled absolute risk of re-revision at two years and death within 90 days are derived considering adjustment variables to be at their reference values (female aged 74 years, ASA grade II, and an NHS practice setting). Analyses were performed using the RMS package in R v. 4 (R Foundation for Statistical Computing, Austria).[14]

Results

Median annual and cumulative consultant RHA volume across all cases was 20 (IQR 11 to 31) and 155 (IQR 65 to 293), respectively. Median annual and cumulative centre RHA volume was 87 (IQR 51 to 131) and 872 (IQR 493 to 1,486), respectively. There were differences in case mix seen between RHA performed by lower- versus higher-volume surgeons. Cases from the top 10% of the consultant volume distribution were more likely to be younger, fitter (lower ASA grade), and performed in the independent sector, and were associated with a lower proportion of intraoperative adverse events as compared to cases performed by lower-volume consultants (Supplementary Table ii). Surgery was performed by a consultant in 89% of cases overall, with dual-consultant operating occurring more commonly for cases where the responsible consultant undertook the lowest annual volumes: 6.1% (85/1,395) versus 1.2% (15/1,205) of cases performed by the lowest versus highest 10% of the volume distribution respectively. A larger proportion of cases performed in higher-volume centres involved more complex surgical techniques (e.g. acetabular bone grafting).

There were 756 (5.8%) re-revision events recorded within the study period, with 513 (4.0%) occurring within two years of index surgery. All cases in the final study cohort were available for multivariable modelling; full details of the Cox proportional hazard model fit characteristics, including confounder adjustment, are presented in the Supplementary Material.

Although of borderline significance, a higher risk of re-revision within two years was seen in association with the lowest annual consultant volumes (Figure 2). The re-revision risk for

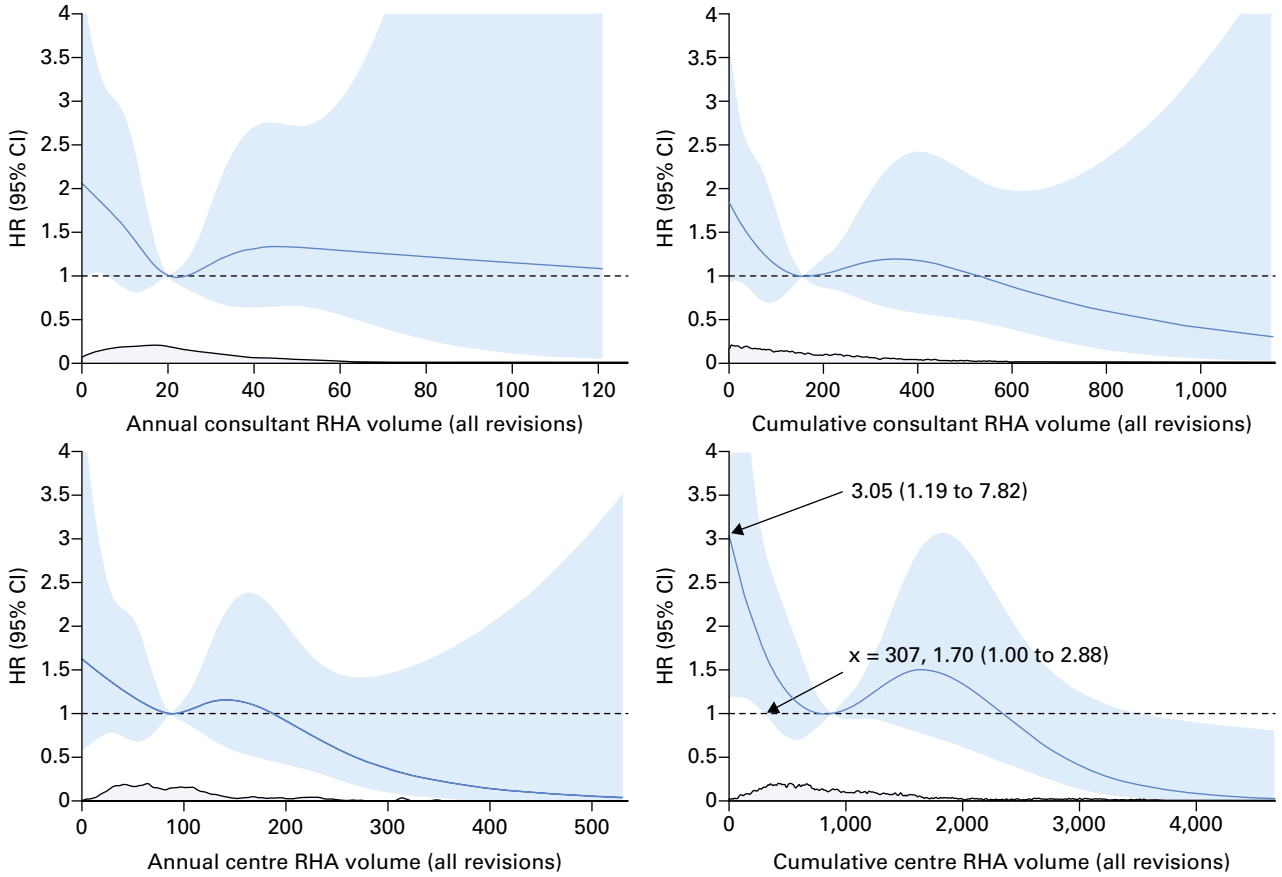

Fig. 3

Plot matrix showing the marginal association of change in surgical volume on the risk of death within 90 days following first-time revision hip arthroplasty (RHA) for aseptic loosening after adjustment for confounding factors. Shaded area represents 95% CI, which converges where the spline is centred (referenced) at the median volume. The grey rug-plot immediately adjacent to the x-axis shows the density distribution of observations upon which the model is based. The annotation indicates (where relevant) the x-axis volume value corresponding to the intersection of the lower 95% CI and a HR of one, highlighting the range of volume where risk is significantly elevated. Coefficients for adjustment variables along with full details of the Cox proportional hazard model fit characteristics are presented in the Supplementary Material.

cases where the consultant performed zero/year (cases where a consultant, at the time of undertaking the case, had performed RHA less frequently than once a year) was associated with a 30% higher risk of re-revision (hazard ratio (HR) 1.31 (95% CI 0.92 to 1.87); absolute risk, 4.84% (95% CI 3.20 to 6.46)) compared to those performed by consultants who had undertaken 20/year (the median consultant annual RHA volume where the spline function was centred, absolute risk 3.72% (95% CI 2.96 to 4.48)). The risk was significantly elevated for annual volumes of five/year (HR 1.28 (95% CI 1.00 to 1.64); absolute risk, 4.74% (95% CI 3.82 to 5.65)), beyond which the lower 95% CI crossed a HR of 1, and there was no significant association between further increases in consultant annual volume and risk of re-revision.

Considering cumulative consultant RHA volume, the risk of re-revision was highest for a consultant's first recorded revision (HR 1.56 (95% CI 1.15 to 2.12); absolute risk, 6.27% (95% CI 4.56 to 7.94)) and remained significantly elevated for the first 24 cases (HR 1.26 (95% CI 1.00 to 1.58); absolute risk, 5.08% (95% CI 4.12 to 6.03)) as compared to the median cumulative consultant volume (absolute risk for 155 cumulative RHAs, 4.06% (95% CI 3.25 to 4.85)).

RHA performed in centres which had cumulatively undertaken fewer than 167 RHAs were at significantly increased risk of re-revision: there was a reduction in HR from 1.70 (95% CI 1.12 to 2.59) (absolute risk, 6.78% (95% CI 4.09 to 9.39)) to 1.33 (95% CI 1.00 to 1.76) (absolute risk 5.32% (95% CI 3.99 to 6.64)) when moving from 0 to 167 cumulative centre volume of RHAs respectively compared to the median cumulative centre volume. The risk of re-revision continued to steadily decline, with no discernible plateau, in association with increasing cumulative consultant and centre volume; however, this did not reach statistical significance (the shaded 95% CI included 1).

There were 95 (0.73%) deaths recorded within 90 days of index surgery. Early postoperative mortality was significantly elevated for RHA performed at centres with the lowest cumulative volumes; the relative risk of death was highest for a centre's first recorded revision (HR 3.05 (95% CI 1.19 to 7.82); absolute risk, 0.68% (95% CI 0.03 to 1.32)) and remained significantly elevated until 307 cases (HR 1.70 (95% CI 1.00 to 2.88);

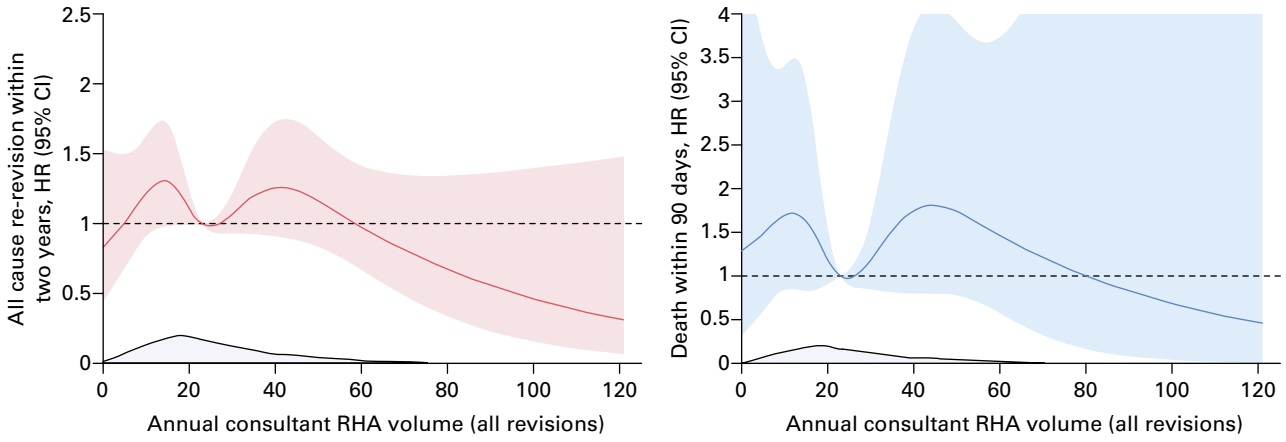

Fig. 4

Plot showing the marginal association of change in annual consultant revision hip arthroplasty (RHA) volume for consultants who had already performed 50 or more cumulative RHAs. HR, hazard ratio.

absolute risk, 0.38% (95% CI 0.18 to 0.58)) as compared with cases performed at centres undertaking the median cumulative centre volume (absolute risk 0.22% (95% CI 0.09 to 0.35)) (Figure 3). Mortality risk continued to decline with increasing volume, becoming significantly lower where centre volume reached 3,533 procedures (HR 0.17 (95% CI 0.03 to 1.00); absolute risk, 0.04% (95% CI 0.00 to 0.11)).

Lower annual consultant RHA volumes, between two (HR 1.96 (95% CI 1.02 to 3.77)) and five (HR 1.81 (95% CI 1.02 to 3.21)) per year, were associated with a significantly higher risk of early postoperative mortality; however, CIs were wide, with HRs only marginally above 1. While there was a trend towards reduced mortality risk in association with increased cumulative consultant revision volume, this did not reach statistical significance.

The association between consultant volume and outcomes was remodelled after excluding all cases (n = 2,539) performed by consultants who had undertaken fewer than 50 cumulative RHAs. This value was chosen empirically by approximately doubling the cumulative consultant volume threshold identified for re-revision shown in Figure 2. The previously observed association between lower annual consultant RHA volume and risk was lost and no meaningful relationship or threshold effect was observed for either re-revision or early postoperative death (Figure 4).

Discussion

This study found a significant association between lower surgical volume of RHA and increased risk of re-revision and 90-day mortality following first-time RHA for aseptic loosening. Patients who underwent RHA performed by consultants who had cumulatively undertaken fewer than 24 revisions were up to 50% more likely to be re-revised within two years. While at the threshold of statistical significance, annual consultant volumes of five/year were associated with an almost 30% greater modelled risk of re-revision and 80% greater risk of postoperative death within 90 days compared to volumes of 20/year. Cases performed at centres which had cumulatively undertaken fewer than 167 RHAs were at up to 70% greater risk of re-revision, and those performed at centres having undertaken fewer than 307 RHAs were at up to three times greater risk of death within 90 days of surgery. Our findings provide important evidence relevant to specialist societies and regional arthroplasty networks regarding the provision of low-volume, high-complexity hip surgery.

Our sensitivity analysis showed that associations between annual consultant volumes and outcomes were not significant for cases performed by consultants who had previously performed at least 50 revisions, suggesting that surgeons who are already experienced may be able to achieve good patient outcomes for RHA for aseptic loosening even if they maintain low annual volumes. This is an important finding, as the setting of mandated annual volume thresholds in isolation, without due consideration of a consultant's cumulative 'career' experience, may have the potential to cause patient harm by reducing the availability of consultant revision expertise, and by incentivizing protectionist practice behaviour among already skilled consultants who may be less willing to share RHA cases with competent but less established junior colleagues. It is encouraging that the lowest-volume consultants were most likely to undertake dual-consultant operating, confirming that surgeons are adapting their practice in the interests of patients.

The positive association between greater surgical volume and improved outcomes has been shown across and within multiple surgical disciplines, including primary lower limb arthroplasty.[15–23] Considering RHA specifically, the findings of our study are supported by previous work. Jeschke et al[10] examined a nationwide healthcare insurance dataset of 17,773 RHAs performed in Germany between 2014 and 2016, finding that 90-day mortality and one-year re-revision surgery were significantly higher in hospitals performing fewer than 53, and fewer than 25, RHAs per year respectively. Their study cohort included a broader case mix comprising RHAs undertaken for any indication except infection, as opposed to our study, which included only first-time single-stage revisions for aseptic loosening, likely explaining why their 90-day mortality (2.6%) and

re-revision (15.4%) events were considerably higher than those observed in our study.

In the USA, Taylor et al[24] used Medicare data between 1993 and 1994 to study the association between hospital patient volume and 30-day mortality following a range of lower limb arthroplasty procedures, including 34,083 RHAs. While their hospital volume exposure variable was derived from combined procedure volumes (not just RHA) and was not adjusted for other factors, they found a significantly lower mortality rate for cases undertaken in the highest-volume centres. Again, their RHA cohort was not restricted to aseptic loosening indication or to first-time revisions; however, it is notable that the relative difference in event rate between the highest (1.4%) and lowest (3.8%) volume centres is broadly consistent with the relative effect sizes seen in our study when comparing the modelled risk of lower-volume versus higher-volume centres (Figure 3). Katz et al[9] used Medicare data for 12,956 RHAs performed between 1995 and 1996; in an adjusted analysis, they found surgeons who performed > ten RHAs annually had a lower 90-day mortality rate than surgeons who performed ≤ three RHAs annually. They identified that annual hospital volumes greater than 50 RHAs were associated with lower rates of hip dislocation, however found non-significant associations between annual hospital RHA volume and mortality.

In contrast, Lindberg-Larsen et al[25] performed an unadjusted analysis of 1,553 aseptic RHAs recorded in the Danish hip arthroplasty registry, finding no significant difference in 90-day mortality when comparing high- (≥ 40 RHAs/year) versus low-volume (≤ 20 RHAs/year) centres. Similarly, Zhan et al[5] reported finding no association between hospital volume and early postoperative outcomes (including mortality) in an analysis of 7,416 RHA cases sampled from a USA administrative healthcare dataset.

Several mechanisms likely contribute to the associations observed in our study and others. The first is the concept that 'practice makes perfect',[26] that surgeons and centres incrementally develop their practice as volume increases, by improving processes (e.g. operative skill, standardization of care pathways) and decision-making (e.g. through multidisciplinary teams, better teamwork, or individual surgeons becoming better at identifying patients likely vs unlikely to benefit from surgery).[27] Additionally, excellence may attract patients whereby consultants and centres with the best outcomes receive the most referrals; thus a higher-volume practice may be the consequence, rather than the cause, of attaining superior outcomes. Furthermore, there are likely competing associations, including consultants with less experience, in recognition of their limitations, referring more complex cases to more experienced colleagues and themselves proportionally undertaking more 'straightforward' cases at lower risk of complications. This may partly explain the non-linear patterns and inflexions seen in our results, particularly at the lower end of the annual volume distributions (Figures 2 to 4).

Our study has several strengths. The use of restricted cubic splines enabled the modelling of non-linear associations between volume and outcome to explore trends and threshold effects. This contrasts with previous research, which has largely used arbitrary thresholds chosen based on the distribution of data, which has limited utility in precisely defining patterns of any volume-outcome associations. Furthermore, our study considered surgical volume at the time of the index RHA procedure, by deriving volume as a time-varying entity which changes daily and uniquely for every consultant and centre. Previous research relating volume to surgical outcomes of RHA has principally derived volume by summating cases performed by consultants and centres over discrete time periods (e.g. calendar years), thus volume will be ascribed inaccurately at the level of individual cases by using volumes derived from a period not relevant to the exact date the index case was undertaken; this may lead to inaccuracy in their use as explanatory variables in survival models predicting outcome. The importance of this approach is further substantiated by prior research which shows that an individual consultant's annual volume can vary substantially over time.[6,17]

We also studied both annual and cumulative volume associations, the latter appearing to demonstrate the strongest associations, which has not been explored previously. RHA cohorts in prior studies have included broader ranges of revision indications, whereas we present the largest published cohort of RHAs for a single indication; this is necessary as the indications for RHA are diverse in terms of both the patient characteristics and the specifics of the procedure performed, thus findings may not be generalizable between revision indications. We focus on first-time single-stage RHA for aseptic loosening: 1) to avoid misclassification of outcome by maximizing confidence that any subsequent revision procedure recorded was unplanned and not part of the patient's planned surgical treatment, and 2) because it is reasonable to assume that there was no clinical urgency to undertake the procedure immediately (in contrast to revision for infection) and thus the patient could have safely waited to be operated on by a high-volume surgeon.

We acknowledge several limitations. While it is plausible that there may be combined consultant and centre volume relationships influencing outcomes, we could not include such interactions in our model due to limited statistical power. We were unable to capture reoperation events such as fixation of a periprosthetic fracture or debridement procedures for infection where the implants were not replaced. We were unable to capture outcomes for RHAs carried out in the independent sector unless they were linkable to civil registration data via at least one recorded HES episode prior to or after their index procedure. However, these cases represented only 7% of the total eligible study population (1,137 of 15,945; Supplementary Table i). While we adjust for key patient factors, the patients who are able and willing to travel in pursuit of 'better' outcomes are likely to have different characteristics than those unable to exercise such choice (e.g. due to deprivation, or impairment of mind or body), which may affect outcomes. This may be a contributing factor to the demographic differences we observed between cases performed by the highest- and lowest-volume surgeons and centres.

Crucially, we are unable to prove causality. We may conclude that the patients operated upon by the highest-volume surgeons and in the highest-volume centres realized the 'best' outcomes, but we cannot conclude that it is the act of being a high-volume consultant or centre, per se, which confers these outcomes.

Therefore, it cannot be inferred that low-volume surgeons who increase their volume will necessarily achieve better outcomes, and indeed research in PHA has suggested that an individual consultant increasing their personal surgical volume may not necessarily result in a reduction in revision risk, but rather may lead to a greater number of cases realizing similar outcomes, potentially resulting in patient harm.[17] Disruption to existing 'free-market' processes, which may have inherently resulted in the highest-performing surgeons and centres achieving greater volumes, may therefore have unexpected consequences.

In conclusion, this study found a significantly higher risk of re-revision and early mortality following first-time single-stage RHA for aseptic loosening when performed by lower-volume consultants and at lower-volume institutions. The findings of this study generally support the move towards the centralization of such cases towards higher-volume units and surgeons; however, while the setting of a minimum consultant annual RHA threshold may be appealing, this study found no strong evidence to support their use in RHA for aseptic loosening when considered in the context of high cumulative consultant volume. Furthermore, our analyses suggest that the greatest risk of poor outcomes occurs during the early phase of a consultant's career, highlighting the importance of education and training. Thus, any redesign of services should include enhanced support for newly appointed surgeons, including dual-consultant operating and mentorship.

Take home message

- This study found a significantly higher risk of re-revision and early postoperative mortality following first-time single-stage revision hip arthroplasty for aseptic loosening when performed by lower-volume consultants and at lower-volume institutions.
- The greatest risk of poorer outcomes occurs during the early phase of a consultant's career, highlighting the importance of education and training.
- The findings of this study support the move towards the centralization of such cases towards higher-volume units and surgeons.

Social media

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Supplementary material

Supplementary tables, figures, and results of multivariable models.

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