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Consultant revision hip arthroplasty volumes and new consultant volume trajectories in England, Wales, Northern Ireland, and the Isle of Man

A STUDY USING THE NATIONAL JOINT REGISTRY DATASET

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Aims

This study describes the variation in the annual volumes of revision hip arthroplasty (RHA) undertaken by consultant surgeons nationally, and the rate of accrual of RHA and corresponding primary hip arthroplasty (PHA) volume for new consultants entering practice.

Methods

National Joint Registry (NJR) data for England, Wales, Northern Ireland, and the Isle of Man were received for 84,816 RHAs and 818,979 PHAs recorded between April 2011 and December 2019. RHA data comprised all revision procedures, including first-time revisions of PHA and any subsequent re-revisions recorded in public and private healthcare organizations. Annual procedure volumes undertaken by the responsible consultant surgeon in the 12 months prior to every index procedure were determined. We identified a cohort of 'new' HA consultants who commenced practice from 2012 and describe their rate of accrual of PHA and RHA experience.

Results

The median annual consultant RHA volume, averaged across all cases, was 21 (inter-quartile range (IQR) 11 to 34; range 0 to 181). Of 1,695 consultants submitting RHA cases within the study period, the top 20% of surgeons by annual volume performed 74.2% of total RHA case volume. More than half of all consultants who had ever undertaken a RHA maintained an annual volume of just one or fewer RHA, however, collectively contributed less than 3% of the total RHA case volume. Consultant PHA and RHA volumes were positively correlated. Lower-volume surgeons were more likely to undertake RHA for urgent indications (such as infection) as a proportion of their practice, and to do so on weekends and public holidays.

Conclusion

The majority of RHAs were undertaken by higher-volume surgeons. There was considerable variation in RHA volumes by indication, day of the week, and between consultants nationally. The rate of accrual of RHA experience by new consultants is low, and has important implications for establishing an experienced RHA consultant workforce.

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Introduction

Revision hip arthroplasty (RHA) surgery is costly, technically demanding, and associated with significantly higher risk of complications in comparison to primary hip arthroplasty (PHA).^{1,2} Prior research from registries has demonstrated an association between lower surgeon volume and poorer patient

outcomes in terms of early (90-day) mortality and reoperation (including re-revision) in revision hip and knee arthroplasty.³⁻⁵ However, a detailed analysis of volume thresholds in the revision setting is yet to be reported. These are important relationships to understand, as complex surgical interventions become increasingly centralized with the

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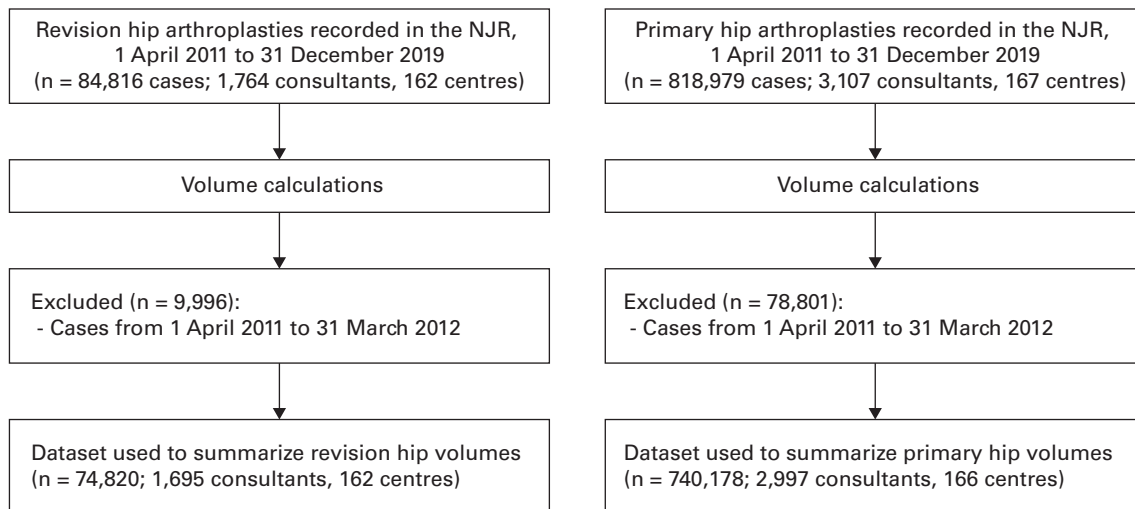


Fig. 1

Study flowchart of revision and primary hip arthroplasty case inclusion eligibility for summarizing consultant annual volumes.

aim of driving improvement in patient outcomes and value for commissioners. Furthermore, there is a need to understand the rate of accrual of hip arthroplasty experience at the beginning of a consultant career to allow appropriate workforce planning and ensure any recommended (or mandated) volume thresholds are achievable, which may require reciprocal adaptation of training pathways and consultant job plans.

The aims of this study were to use data from the National Joint Registry (NJR) for England, Wales, Northern Ireland, and the Isle of Man to describe the variation in the volume of RHA undertaken at consultant surgeon level, explore associations with revision indication, day of surgery (midweek vs weekend), and a consultant's PHA volume, and to describe the rate of accrual of PHA and RHA volume for newly established consultants.

Methods

Data source. We received data for all PHAs (including total joint replacement and resurfacings) and RHAs recorded in the NJR between 1 April 2011 and 31 December 2019; dates were chosen to correspond with the inception of mandatory reporting to the NJR by all healthcare providers. There were no other exclusions, and the study population comprised all submitted procedures, including first-time revision of PHA and any subsequent re-revision procedures performed in the public or independent (private) sector. The dataset included unique identifiers for each responsible consultant surgeon. For RHA cases, the indication for revision was categorized hierarchically into six discrete groups: infection, trauma, dislocation, adverse reaction to metal debris (ARMD), aseptic loosening (including lysis), and other aseptic (any other noninfected indication not captured by the other groups).

Annual volume calculations. For each individual RHA, we determined the annual number of RHA cases recorded (for all indications as well as broken down by revision indication) by the named responsible consultant in the 12 months immediately

prior to the day each index RHA was performed. For each PHA, identical methods were used to derive annual consultant PHA volume. The first 12 months of data from the study period (all cases from 1 April 2011 to 31 March 2012) were then excluded to allow a 'run-in' period from the inception of mandatory reporting in the registry before volume calculations were summarized. This method of annual volume calculation produces a data point of volume for each RHA case undertaken. This makes calculation of summary statistics more complex than presenting simple counts of RHA procedures, but it is crucial for investigating the provision of RHA expertise across the population from a public health perspective, and for later work in analyzing relationships between volume and outcome.

Summarizing annual volume across all RHA cases. We firstly summarize the above-derived annual volumes as a single estimate – a median across all RHA cases (i.e. all cases performed by the whole 'population' of consultants) – followed by aggregating and summarizing data by year, revision indication, geographical region, and day of the week.

Comparing volume between consultants. To compare annual volumes between individual consultants for the entire period of observation (2012 to 2019), for every consultant we summarized the annual volumes derived for all their RHA cases recorded over the whole study period using the mean and 95% centile range. Caterpillar plots and histograms were then used to compare these derived means and 95% centile ranges between consultants, to describe the variation and the respective total number of RHAs performed. Identical methods were used to summarize PHA volume.

New consultant volume trajectories. We identified a cohort of 'new' hip arthroplasty consultants who recorded their first PHA as a responsible consultant in the NJR on or after 1 April 2012. To increase confidence that we were identifying truly 'new' consultants, we further excluded any consultant who recorded a PHA prior to 1 April 2012 using a supplementary dataset of all NJR hip arthroplasties performed between April 2003 and

Table I. Number of revision hip arthroplasties and annual consultant volumes across all cases by indication and year.

Variable	Year								All years
	2012*	2013	2014	2015	2016	2017	2018	2019	
Revisions, n	8,160	10,213	10,174	9,864	9,341	9,357	8,996	8,715	74,820
Revisions by indication, n (%)									
Aseptic loosening	3,114 (38.2)	3,781 (37.0)	3,708 (36.4)	3,549 (36.0)	3,289 (35.2)	3,248 (34.7)	2,918 (32.4)	2,795 (32.1)	26,402 (35.3)
Infection	1,020 (12.5)	1,315 (12.9)	1,470 (14.4)	1,616 (16.4)	1,453 (15.6)	1,563 (16.7)	1,592 (17.7)	1,604 (18.4)	11,633 (15.5)
Dislocation	949 (11.6)	1,261 (12.3)	1,371 (13.5)	1,347 (13.7)	1,329 (14.2)	1,457 (15.6)	1,467 (16.3)	1,415 (16.2)	10,596 (14.2)
Other aseptic	1,309 (16.0)	1,435 (14.1)	1,257 (12.4)	1,089 (11.0)	1,052 (11.3)	913 (9.8)	803 (8.9)	761 (8.7)	8,619 (11.5)
Trauma	689 (8.4)	998 (9.8)	1,196 (11.8)	1,221 (12.4)	1,238 (13.3)	1,321 (14.1)	1,375 (15.3)	1,397 (16.0)	9,435 (12.6)
ARMD	1,079 (13.2)	1,423 (13.9)	1,172 (11.5)	1,042 (10.6)	980 (10.5)	855 (9.1)	841 (9.3)	743 (8.5)	8,135 (10.9)
Median annual consultant volume of RHA prior to case (IQR)†									
All revisions	25 (13 to 45)	25 (12 to 42)	23 (11 to 36)	21 (12 to 34)	19 (11 to 33)	19 (10 to 31)	19 (10 to 29)	18 (10 to 28)	21 (11 to 34)
Aseptic loosening	11 (5 to 18)	10 (5 to 16)	9 (4 to 14)	8 (4 to 13)	8 (4 to 13)	8 (4 to 13)	7 (3 to 11)	6 (3 to 11)	8 (4 to 14)
Infection	4 (1 to 8)	4 (1 to 7)	3 (1 to 7)	4 (1 to 7)	3 (1 to 6)	4 (1 to 7)	4 (1 to 7)	3 (1 to 7)	4 (1 to 7)
Dislocation	3 (1 to 5)	3 (1 to 5)	2 (1 to 4)	3 (1 to 5)	2 (1 to 5)	3 (1 to 5)	3 (1 to 5)	3 (1 to 5)	3 (1 to 5)
Other aseptic	4 (2 to 9)	4 (2 to 9)	3 (1 to 6)	2 (1 to 4)	2 (1 to 5)	2 (1 to 4)	2 (0 to 3)	1 (0 to 3)	2 (1 to 5)
Trauma	2 (0 to 3)	2 (1 to 4)	2 (1 to 4)	3 (1 to 5)	2 (1 to 5)	2 (1 to 5)	3 (1 to 5)	3 (1 to 5)	2 (1 to 5)
ARMD	7 (2 to 17)	7 (2 to 15)	6 (2 to 12)	4 (1 to 9)	4 (1 to 8)	4 (1 to 8)	3 (1 to 6)	3 (1 to 6)	4 (1 to 10)

Example interpretation - for the 1,453 revisions for infection undertaken in 2016, on average the responsible consultant had recorded a median of three (IQR 1 to 6) revisions for infection in the 365 days prior to a case.

*2012 includes April to December data only.

†The number of revisions the responsible consultant had undertaken, on average, across all RHA cases recorded for the specified indication. ARMD, adverse reaction to metal debris; IQR, interquartile range; RHA, revision hip arthroplasty.

Table II. Centiles of consultant revision hip arthroplasty case volume by year.

Variable	Annual number of RHA cases needed for a consultant to reach the specified volume centile by year, n (%)*						
	2013	2014	2015	2016	2017	2018	2019
Consultants, n†	848	867	862	907	904	913	889
Centile of consultant annual case volume							
25th	2 (3.2)	2 (3.3)	2 (3.4)	2 (4.2)	2 (4.1)	1 (2.6)	2 (4.2)
50th	6 (11.1)	7 (11.7)	7 (13.0)	6 (12.3)	6 (12.4)	6 (12.3)	6 (12.1)
75th	18 (33.7)	17 (35.2)	17 (36.8)	15 (36.0)	15 (35.3)	15 (36.3)	14 (39.7)
90th	31 (62.9)	30 (63.9)	30 (66.5)	26 (64.9)	26 (63.7)	25 (65.9)	23 (66.5)
100th	95 (100)	79 (100)	72 (100)	68 (100)	82 (100)	61 (100)	85 (100)

*The cumulative RHA volume percentage reported in parentheses includes cases by those consultants who recorded equal to the indicated annual volumes (which may also include consultants in higher volume centiles due to clustering in lower volumes) and all cases by those consultants who recorded lower annual volumes.

†The number of unique responsible consultants who submitted one or more RHA in the calendar year for which yearly volume centile distributions are calculated. 2012 data are not shown as includes only April to December cases. Example interpretation - in 2016 there were 907 consultants who recorded one or more RHA cases; to reach the 90th case volume centile in 2016 (i.e. the top 10% of consultants when ordered by number of cases each recorded in 2016), a consultant would need to have recorded 26 RHA; in 2016, 64.9% of all RHA cases were performed collectively by all consultants who had recorded 26 or fewer cases that year. Hence, 35.1% (100% to 64.9%) of RHA cases were performed by consultants who had recorded more than 26 RHA that year.

RHA, revision hip arthroplasty.

December 2019. We examined each 'new' consultant's practice to determine how their PHA and RHA annual volume changed with respect to their cumulative time in consultant practice since the date of their first PHA. All consultant RHA volumes after April 2011 was measured, even if prior to a consultant's first PHA date.

Volume trajectories for all new consultants were then aligned and aggregated by time in practice, and distributions were summarized (median, interquartile range (IQR) and 2.5th to 97.5th centiles (95% centile range) continuously over time from the beginning of consultant PHA practice to maximum

available follow-up (31 December 2019), at which time consultants were censored by removal from the denominator of cases for summarization at subsequent follow-up times. We additionally censored consultants from the trajectory denominators the day after they recorded their last PHA in the dataset, otherwise the consultant denominator is likely to be overestimated, resulting in the trajectory summary distributions being skewed and less informative as consultants may have ceased clinical practice before the end of follow-up (e.g. due to retirement, change in job plan or career, relocation, or death). Consultants were not censored after their last revision as this would lead

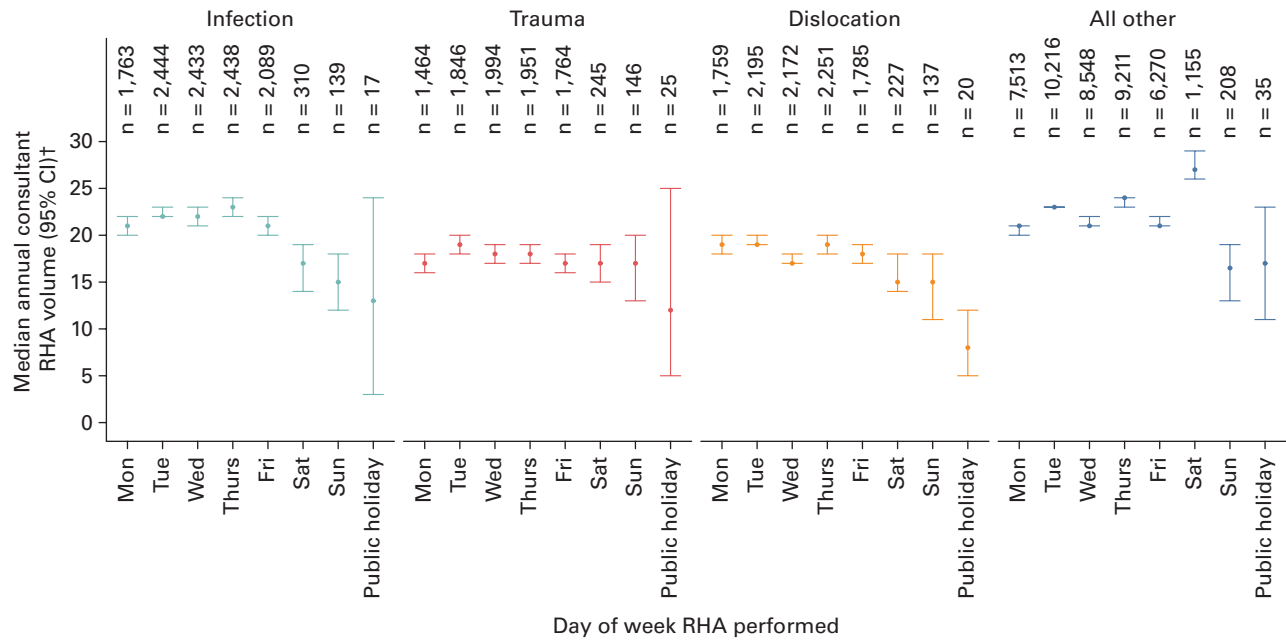


Fig. 2

Overall median annual volume of revision hip arthroplasty (RHA) undertaken by the responsible consultant prior to an index RHA procedure for given revision indication and by day of the week. Point and error bar shows median and 95% confidence intervals (CIs) for all cases (annotation shows case numbers). CIs are derived from bootstrapped samples using a minimum of 2,000 replicates. Annual volumes include experience of all revision indications undertaken by the responsible consultant and not restricted to the specified indication subgroup. 'Public holiday' represents all non-weekend public and bank holidays in England during the observed period. See Supplementary Material for list of reference dates used.

consultants with longer follow-up to be a selected (biased) group of revision-active surgeons, and would not produce informative data on the accrual of RHA volume for the whole cohort of active arthroplasty consultants. We first report volume trajectories for all new consultants undertaking PHA, to describe RHA experience for all new hip arthroplasty surgeons maintaining a PHA practice. Second, we present analyses for subgroups of all new consultants who reached (but did not necessarily maintain) five, ten, 15, or 20 annual RHA volume thresholds at any point during the study period to provide informative data on the length of time, in independent consultant practice, taken for consultants to reach and consistently maintain these annual volumes of RHA.

Research approvals. Study approval was granted by the NJR and UK Healthcare Quality Improvement Partnership (ref: HQIP360). This study was supported by grants from Orthopaedic Research UK and the British Hip Society.

Statistical analysis. Overall annual volume data (considering all cases collectively) was positively skewed, therefore median, IQR, 95% centile range, or 95% confidence intervals (CIs) (derived from a minimum of 2,000 bootstrap samples) are reported. Annual volume within individual consultants approximated a symmetrical, non-normal distribution; therefore, mean and 95% centile ranges are reported. The Pearson correlation coefficient was used to assess any correlation between consultant PHA and RHA annual volumes. A p-value < 0.05 was deemed statistically significant. Analyses were performed in R v. 4 (R Foundation for Statistical Computing, Austria).

Results

There were 84,816 RHA and 818,979 PHA procedures recorded in the NJR between 1 April 2011 and 31 December 2019. In total, 1,764 unique consultants recorded at least one RHA during this period of which 98% (1,728 consultants) also submitted at least one PHA. Of 3,107 consultants recording a PHA, 56% (1,728) recorded at least one RHA during the period. The number of eligible cases included for summarizing annual volumes are described in Figure 1. There has been a gradual decline in the total number of revisions recorded year-on-year, an increase in the relative proportion of RHA undertaken for infection, trauma, and dislocation, and a relative decrease in the proportion for ARMD and aseptic loosening (Table I).

Annual consultant volume across all RHA cases. Using all 74,820 eligible RHA cases as the unit of analysis, the overall median annual consultant RHA volume was 21 (IQR 11 to 34). Overall annual RHA volume has declined in recent years, likely driven, in part, by a reduction in the large volumes of revision for ARMD and aseptic loosening undertaken in the earlier years of the study period (Table I; data for each NJR region are presented in Supplementary Material). RHA performed for acute indications (infection, trauma, and dislocation) were performed by lower-volume consultants at weekends and on bank holidays compared to mid-week (Figure 2) – e.g. RHA for infection recorded on a Wednesday were performed by consultants maintaining a median annual RHA volume of 22 (95% CI 21 to 23) compared to a median of 15 (95% CI 12 to 18) for cases performed on Sundays, a relative difference of more than 40%.

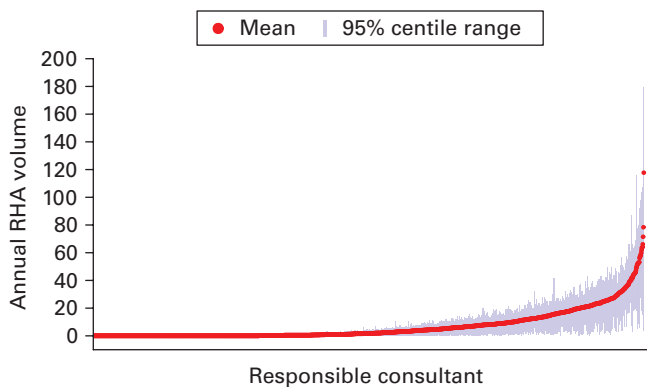


Fig. 3

Caterpillar plot showing mean (red points) and 95% centile range (blue shaded range) of annual revision hip arthroplasty (RHA) volume for each of the 1,695 individual consultants who undertook RHA cases between 1 April 2012 and 31 December 2019. Consultants are ordered on the x-axis by ascending consultant mean annual volume. The individual red dots for each consultant appear collectively as a solid line due to overlapping adjacent consultants with similar mean annual volume until reaching the far-right hand side of the chart. An average annual volume of 0 indicates that for each RHA the consultant did they had, on average, no RHA experience in the trailing 12 months prior to undertaking a case – for example, a consultant who recorded a RHA less frequently than once every 12 months, or a consultant submitting only one revision during the period of observation.

Variation in RHA volume between consultants. Yearly numbers of consultants submitting RHA, along with centiles of distribution of annual consultant RHA case numbers, are shown in Table II and further broken down by indication and NJR region in the Supplementary Material. In recent years (2017 to 2019), on a yearly basis, half of all active RHA consultants were submitting six or more RHAs per year and the top 25% consultants by volume were submitting between 14 and 15 or more per year. Analysis of consultant volume by NJR region showed higher-volume RHA surgeons existed in all regions, rather than being confined to a particular geographical area.

We then examined how annual volume varies between individual consultants over the whole study period (2012 to 2019) (Figure 3) and observed a highly skewed distribution (Figure 4). Across the whole study period, individual consultant mean annual RHA volumes ranged from 0 to 118, with a median of 1.7 (IQR 0 to 9.3) and 69% of all consultants (1,171/1,695) maintained an annual volume of seven or less. Overall, the highest 20% consultants by annual volume collectively performed 74.2% of the total RHA workload. While a high proportion of consultants recorded very low volumes of RHA during the study period, they collectively contributed very few cases as a proportion of the total volume of RHA cases done; in total, the lowest 50% of consultants by annual volume contributed only 2,168 cases, representing 2.9% of the total volume of RHA performed. The proportion of consultants who recorded informative ranges of RHA annual volumes, along with a comparison of the corresponding proportion of total RHA cases performed, are illustrated in Figure 5. Lower-volume revision consultants were more likely to undertake revision for acute indications as a proportion of their total RHA cases (Figure 5).

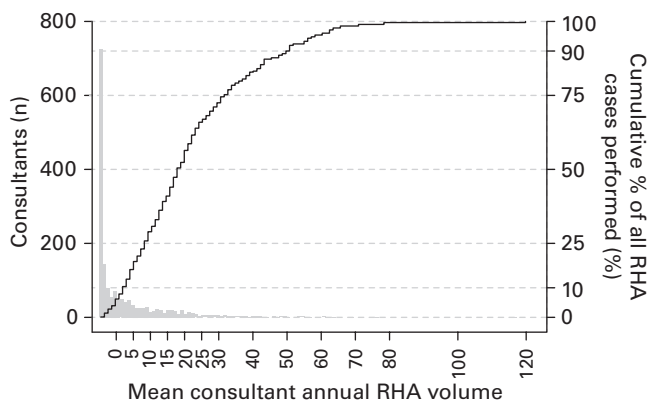


Fig. 4

Histogram showing the distribution of consultant mean annual revision hip arthroplasty (RHA) volumes for all consultants who undertook RHA between 1 April 2012 and 31 December 2019. Consultant mean annual volumes were grouped by rounding down to the nearest integer – ‘0’ bar represents all consultants ($n = 724$) whose mean annual volume over the period of observation ranged from 0 to less than, but not including, one RHA per year. The black line indicates the cumulative proportion of total RHA cases performed by consultants at or below each indicated annual volume group. Horizontal dashed lines indicate the 10th, 25th, 50th, 75th, and 90th centiles of this distribution.

A consultant’s mean consultant annual RHA volume was strongly correlated with their mean PHA annual volume (Pearson’s correlation coefficient 0.73 (95% CI 0.70 to 0.75); $p < 0.001$; Figure 6).

Consultant volume trajectories. We identified 1,081 new consultants who recorded their first PHA as responsible consultant on or after 1 April 2012, 466 (43%) of whom also recorded at least one RHA by 31 December 2019. PHA and RHA annual volume trajectories over time relative to the beginning of consultant practice (date of a consultant’s first PHA) are shown in Figure 7, with detailed analysis comparing primary and revision volumes according to threshold values of revision cases shown in Figure 8 and Supplementary Figure a. New consultants recorded their first RHA as a responsible consultant a median of 169 days (IQR 35 to 478) following their first PHA in consultant practice. There was substantial variation in volume trajectories across the new consultant cohort, indicated by markedly large 95% centile ranges. In 237 new consultants with follow-up available after five years in clinical practice, the median annual volume attained were 30 PHAs (IQR 3 to 68) and 0 RHAs (IQR 0 to 4), with 67% of new consultants ($n = 159$) having undertaken at least one RHA by this point.

Subgroups of new consultants who reached annual RHA volumes of \geq five, \geq ten, \geq 15, and \geq 20/year at any time by 31 December 2019 were identified and their aggregated volume trajectory distributions plotted (Figure 8). There were 83 consultants who achieved \geq 15/year annual RHA volume. It took these consultants a median of 1.9 years (IQR 1.2 to 3.1) to first reach this annual volume; however, very few of these consultants then immediately maintained this volume, and it took between four and six years before this annual volume was

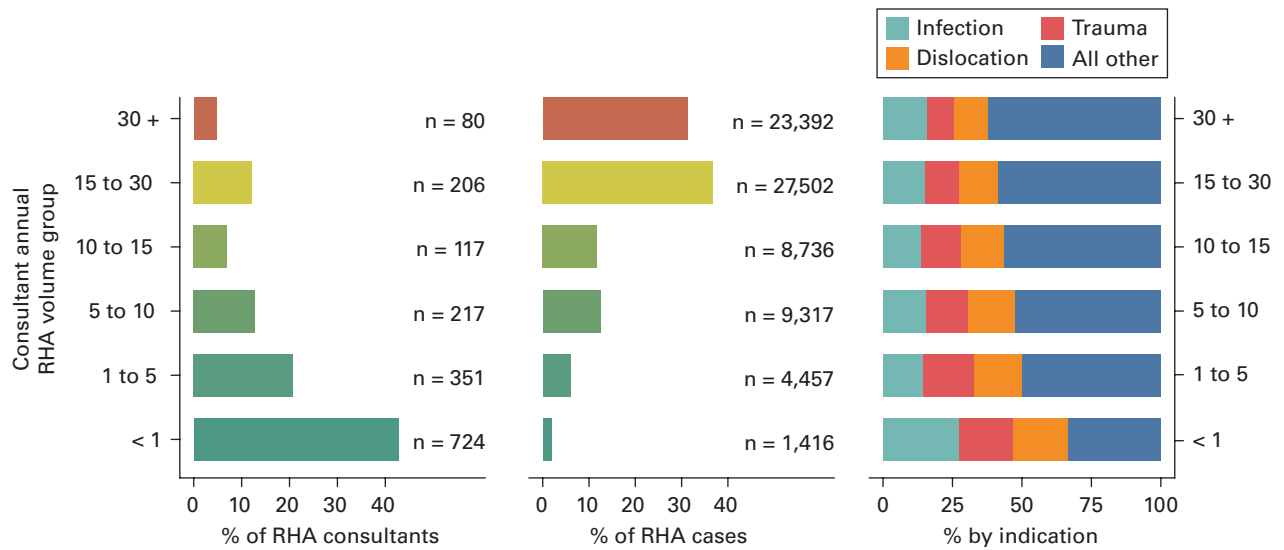


Fig. 5

Compound bar chart showing the relative proportion of consultants who, over the study period, recorded informative ranges of mean annual revision hip arthroplasty (RHA) volumes (left), the corresponding proportion of total RHA cases performed collectively by each RHA volume group (centre), and the proportion of these cases represented by each indication (right). The annotations indicate the total number of consultants included in each volume category (left), and the total number of RHA cases performed by consultants in each volume category (centre).

consistently maintained by more than half of the consultants in this subgroup. These higher-volume subgroups maintained substantially larger volumes of PHA than the whole group of new consultants.

Discussion

The principal findings of this study were that the majority of RHAs were undertaken by higher-volume surgeons, with the top 20% of consultants by volume contributing almost three-quarters of total RHA case volume. There was considerable variation in consultant RHA volumes by day of the week and between consultants nationally, with half of all consultants who had ever recorded a RHA between 2012 and 2019 maintaining an annual volume of one or fewer RHAs and collectively contributing less than 3% of the total case volume; additionally, the rate of accrual of RHA experience by new hip arthroplasty consultants is extremely low and those who eventually undertake ≥ 15 /year may take more than five years to begin to consistently maintain this volume. Our study provides important findings relevant to specialist societies and regional arthroplasty networks regarding service delivery in the context of the move towards the centralization of low-volume, high-complexity surgery and workforce planning specific to RHA.

We additionally demonstrate that lower-volume consultants were more likely to undertake RHA for acute indications as a proportion of their practice. Furthermore, and likely related to this, we found significant variation in the volumes of RHA undertaken by consultants for acute indications at weekends. RHAs undertaken for infection on a Wednesday were performed by consultants who collectively had a 40% greater RHA annual volume experience than revisions undertaken for infection on a Sunday. This trend could be driven,

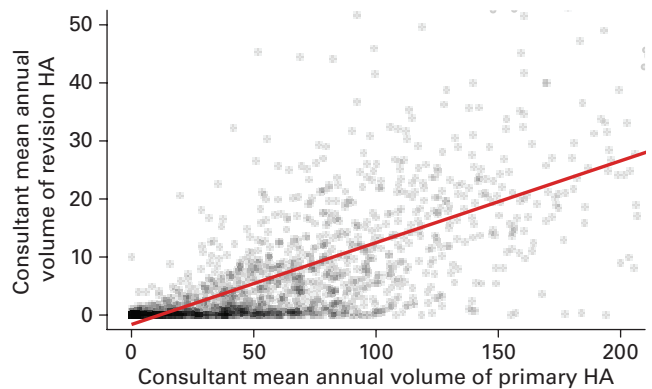


Fig. 6

Scatter plot of consultant mean annual volumes for primary (PHA) and revision hip arthroplasty (RHA). Consultants who did not record a PHA are considered to have a mean annual PHA volume of 0. The x- and y-axes are truncated at 200 and 50, respectively. Each point represents an individual consultant with values derived from that consultant's cases over the entire period of observation. Pearson's correlation coefficient 0.73 (95% confidence interval 0.70 to 0.75); $p < 0.001$.

in part, by consultants with less experience being obliged on clinical grounds to perform RHA for emergency admissions out of hours (e.g. for sepsis source control in a deteriorating patient) rather than deferring the case to be operated on by a more experienced revision surgeon during normal mid-week working hours. For such patients, the risk of adverse outcome is likely further compounded by the inherent reduced access to clinical expertise (e.g. multidisciplinary teams) and infrastructure for case planning outside normal working hours. This may

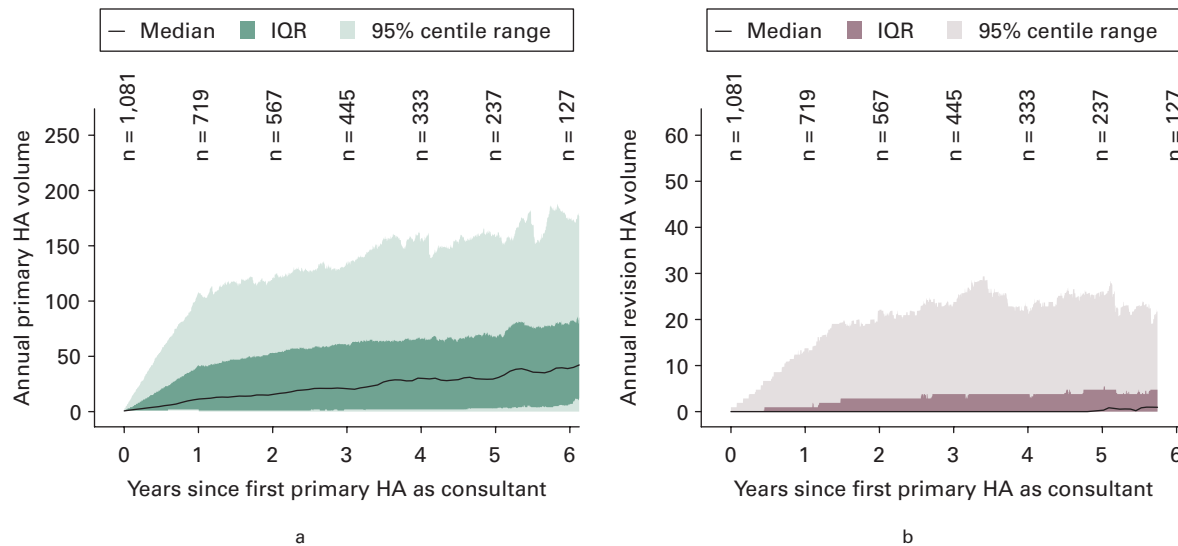


Fig. 7

a) Primary (PHA) and b) revision hip arthroplasty volume trajectories for new consultants who began PHA practice on or after 1 April 2012. Annotations indicate the number of consultants available for summarization at each follow-up period. Consultants are censored from the denominator at the end of available follow-up (31 December 2019), or immediately following their last recorded PHA. Summary distributions are not presented after the denominator reaches less than 10% of the origin consultant denominator (as at time = 0). IQR, interquartile range.

represent an unmet need for RHA expertise, and future work must closely examine these cases, their host institutions, and subsequent outcomes.

Direct comparison of volumes presented in this study with others is challenging for several reasons. First, consultant and centre volumes are inconsistently calculated within the literature; methods have included simply summing cases done by individual consultants over discrete calendar years (analogous to data which we present in Table II),^{3,4,6} to more complex methodologies also presented in our paper (Table I) and previously by Sayers et al,⁷ which considers volume as a dynamic, time-varying entity which changes daily and uniquely for every consultant, with the accrual of new case experience and the loss of historical case experience which fall outside the trailing window of observation as time advances. The former of the two methods is undesirable if calculations are to be used as explanatory variables in survival models to predict case outcome, as failing to measure consultant volume as a time-varying entity can lead to ascribing volumes incorrectly at the level of individual cases by using consultant volumes aggregated from cases performed at a future date in the calendar year (i.e. including experience gained after the date of the index case). This is especially important as the extent to which, at a specific moment in time, an individual consultant's case volume differs relative to their average for the period of observation may be substantial over time, as evidenced by the large 95% centile ranges of individual consultant volumes recorded during our study and presented in Figure 3. Furthermore, totalling annual case numbers and using their distribution between consultants to draw conclusions is underpinned by the potentially false assumption that all consultants were in clinical practice and able/eligible to submit cases for the full calendar year; summarizing annual volumes across individual RHA cases avoids this problem.

Second, summarizing volume distributions between consultants is strongly influenced by the period being observed, particularly when dealing with large denominators of low-volume surgeons. Within the NJR, while the higher-volume RHA consultants usually contribute cases consistently year-to-year, in any given year there exists a proportion of new consultants (who are commonly low-volume surgeons and may record only a single case), such that a large denominator of low-volume surgeons is created when data are aggregated over several years. This effect can be seen in our study, where distributions of case numbers submitted by consultants active within a single a calendar year (Table II) are considerably larger than when averaged over the whole period of observation. Thus, comparing volume distributions between studies or analyses conducted over different periods of time may be impossible.

Notwithstanding the above, findings from this study are broadly consistent with those reported in the literature. Kalson et al⁶ examined volumes of 20,857 revision knee arthroplasties (RKAs) across 1,353 consultants in the NJR over a recent three-year period. They found similarly high proportions of low-volume surgeons, with 75% of surgeons performing fewer than seven RKAs annually and the 29% highest-volume surgeons performing 75% of the total RKA workload. In Scotland, Farrow et al⁸ conducted a review of all revision RKAs undertaken in 2019, finding 64% of surgeons performed fewer than five RKAs and 48% of surgeons performed fewer than two RKAs.

In England, the Getting it Right First Time (GIRFT) initiative has identified revision arthroplasty as an area in which patient outcomes and health service costs would benefit greatly from rationalized practice.⁹ GIRFT identified that between 2011 and 2012, 82% of surgeons undertook ten or fewer RKAs, and 62% of consultants undertook ten or fewer RHAs annually. GIRFT

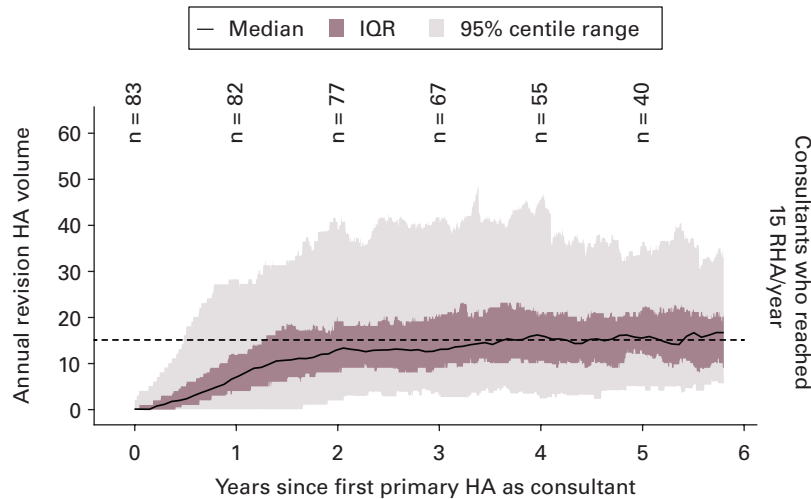


Fig. 8

Revision hip arthroplasty (RHA) volume trajectories for new consultants who began a primary hip arthroplasty (PHA) practice on or after 1 April 2012 and reached an annual threshold volume of 15 RHA/year at any point prior to 31 December 2019. The time at which more than 50% of consultants consistently maintained this volume can be approximated by the intersection of the median line with the dashed horizontal threshold line.

Annotation indicates the denominator of consultants available for summarization at each follow-up period. Summary distributions are not presented after the denominator reaches less than 25 consultants. Example interpretation – there were 83 new consultants who, at any time between 1 April 2012 and 31 December 2019, reached an annual volume of 15 or more RHA per year. We then observe this group of 83 consultants' annual volumes over time from the date when they first started a PHA consultant practice (which is unique for every consultant) until their last recorded PHA or until being censored (see Methods). After one year in practice, there were 82 consultants (one consultant had been censored) in whom the median RHA volume performed was 7/year (interquartile range (IQR) 4 to 12; 95% centile range 0 to 28). There were 77 consultants who had been in practice for two years in whom the median RHA volume performed was 14/year (IQR 8 to 20; 95% centile range 2 to 40). The dashed threshold line intersects the median line at around four to five years, indicating that half of the cohort of all consultants who ever reached a RHA volume of 15/year were maintaining an annual volume of 15/year after four to five years in practice.

has asked specialist societies to provide guidelines on minimum surgeon and centre volumes, although the precise threshold for such remains an outstanding research question and the subject of future work by our group. The formation of complex arthroplasty networks has begun in several regions with favourable impacts reported,¹⁰ and is supported by recent work to stratify RHA complexity.¹¹

We observed large variation in the RHA volume trajectories of new consultants entering practice, which is likely explained by the heterogeneous nature of clinical practice among individual consultants and the healthcare organizations in which they work. The volumes achieved by new consultants may be influenced by several different determinants, including the scope of their practice, their individual job plans, the needs of the health service or hospital, the healthcare needs of their local population, and the personal preference of a consultant to maintain a RHA practice. The setting of any mandatory minimum surgeon and centre volumes has consequences not only for service reorganization and infrastructure, but for training and workforce planning. Volume trajectories for cohorts of new consultants provided by our study are novel, and have not been reported previously in a national cohort. These confirm that RHA represents a very small proportion of most consultants' surgical practice. Even considering all active RHA consultants in recent years, only the top 25% of all surgeons performing RHA by volume in a given calendar year approximate annual volumes of 15/year. Thus, new consultants cannot be expected to accrue RHA expertise and volume without such

a clinical practice being actively cultivated by formal integration into job plans and departmental care pathways. While costly from a resourcing perspective, dual-consultant operating for high complexity is one important process by which centres may help support the sharing of volume and expertise for such cases within a department, which may be especially beneficial to new consultants.

We acknowledge several limitations. First, we received data only for HA, and we expect that many consultants' practices will likely also include primary and/or revision knee arthroplasty, which may bring transferrable skills influencing outcomes. Volume calculations will not capture relevant surgical experience acquired by consultants prior to the start of their NJR records, such as skills acquired during surgical training and specialist fellowships.¹² We acknowledge that the responsible consultant may not always be the lead (operating) consultant, but in 90% of cases it was. We focused our analyses on reporting trailing annual volumes of HA, however any future work relating volumes to outcome must also explore longer time windows for measuring volume, in addition to considering the impact of cumulative volumes for PHA and RHA along with combined primary and revision volume. Finally, we chose not to analyze data for 2020 onwards in order to avoid any impact of COVID-19 on our analyses; we acknowledge COVID-19 is likely to have a detrimental impact on volumes at both fellowship and consultant level.

While the overwhelming majority of RHA cases are performed by higher-volume surgeons, significant variation

exists nationally in the volumes of RHA undertaken by individual consultant surgeons. Low-volume consultants comprised the majority of the consultant workforce between 2012 and 2019, but contributed a very low proportion of the total number of RHA work done. Lower-volume surgeons were more likely to undertake revisions for urgent indications, such as infection, and to do so at weekends and on public holidays. The rate of accrual of RHA experience by most new consultants is low and has crucial implications for establishing an experienced RHA consultant workforce.



Take home message

- The majority of revision hip arthroplasties (RHAs) were undertaken by higher-volume surgeons, with the top 20% of consultants by volume contributing almost three-quarters of total RHA case volume.
- There was considerable variation in consultant RHA volumes by day of the week and between consultants nationally, with half of all consultants who had ever recorded an RHA between 2012 and 2019 maintaining an annual volume of one or fewer RHAs and collectively contributing less than 3% of the total case volume.
- The rate of accrual of RHA experience by new hip arthroplasty consultants is low, and those who eventually undertake 15 RHAs/year may take more than five years to begin to consistently maintain this volume.

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Supplementary material



Supplementary tables, figures, and analysis by geographical region.

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