

Temporal Trends and Survivorship of Total Hip Arthroplasty in Very Young Patients: A Study Using the NJR Dataset

Aim This study aimed to describe temporal trends and survivorship of total hip arthroplasty (THA) procedures in very young patients (aged ≤ 20 years).

Patients and Methods A descriptive observational study was undertaken using data collected from the National Joint Registry (NJR) for England, Wales, Northern Ireland and the Isle of Man between April 2003 and March 2017. All patients aged ≤ 20 years at the time of undergoing primary THA were included and the primary outcome was revision surgery. Descriptive statistics were used to summarize the data and Kaplan-Meier estimates calculated for cumulative implant survival.

Results There were 769 arthroplasty procedures performed in 703 patients. Eight patients died and 35 THAs were revised during the follow-up period. The use of metal-on-metal (MoM) bearings and resurfacing procedures declined from 2008. The most frequently recorded indications for revision were loosening (20%) and infection (20%), although the absolute risk of these events occurring within the cohort was low at 0.9%. Factors associated with lower THA survival were MoM and metal-on-polyethylene (MoP) bearings and resurfacing arthroplasty (versus ceramic-on-polyethylene [CoP] and ceramic-on-ceramic [CoC] bearings, $p=0.002$), and operations performed by surgeons with a lower frequency of very young patient THAs recorded in the NJR (versus those with ≥ 5 recorded operations, $p=0.030$). Kaplan-Meier estimates suggested 96% (95% confidence interval [CI] 94-98%) survivorship of implants across the cohort at 5 years.

Conclusion Within the NJR, the overall survival for very young patients undergoing THA exceeded 96% over the subsequent five years. In the absence of studies that can better account for differences in patient characteristics, surgeons should consider the association between early revision and

implant type, volume of young hip arthroplasties performed and bearing surface when performing
THA in children and young adults.

Introduction

End-stage hip arthritis is the final common outcome of many diseases that can affect children and adolescents(1-3) The pain and loss of function associated with advanced hip disease has a predictably detrimental effect on mental and physical health in these young patients. Total hip arthroplasty (THA) is an effective method of reducing pain and improving quality of life(1, 4-7), although there are concerns about the suitability of THA for very young patients due to reduced implant longevity and the potential need for multiple revision procedures.(8-12)

Revision rates are inversely proportional to patient age(9-11, 13-15) and alternatives to THA include resection arthroplasty, arthrodesis and redirection osteotomies of acetabulum and/or proximal femur.(16-21) These procedures can be very successful in relieving pain and restoring function, although such joint preserving operations carry their own risks and may complicate future arthroplasty procedures.(12, 22, 23) The fundamental principle of prolonging good function in a native joint is of particular relevance in the very young patient, however the ability of a surgeon to discuss all the options with their patient suffering from advanced hip disease is complicated by the paucity of literature on the survivorship of THA in this group. The most recent meta-analysis undertaken to guide these decisions was limited to pooling data from only 736 procedures, despite including 16 studies.(1)

The present study sought to correct this deficit by providing evidence from the largest prospective arthroplasty registry in the world.(24) In particular, it aimed to describe the temporal trends and survivorship of THA in patients aged ≤ 20 years, as well as to identify factors that are associated with early arthroplasty failure.

Methods

An observational cohort study was performed using data collected from the National Joint Registry (NJR) for England, Wales, Northern Ireland and the Isle of Man. The NJR commenced data collection

on 1st April 2003. It was developed as a surveillance tool to identify failing implants and has since grown to become the largest arthroplasty registry in the world.(14) There were 793,636 primary THA procedures recorded within the NJR up until 8th March 2017. Case capture is high (median 96% of hips in 2016)(25) and linked to payment of the Best Practice Tariff to NHS hospitals.(26) Only fourteen NHS organisations (10%) submitted <75% of eligible cases (median 65% estimated case capture) in 2016.(25)

We included all individuals aged ≤ 20 years old that had a primary THA recorded within the NJR since its inception. No exclusion criteria were applied.

The patient variables extracted from the NJR were age, sex, body mass index (BMI), and American Society of Anesthesiologists (ASA) score. The operation variables were indication(s), laterality, approach, procedure name, implant details (cup type and composition, liner type and composition, head type and composition, stem type and composition) and use of cement. The “indication” variable was recoded using an algorithm designed to replace potential secondary diagnoses (e.g. “osteonecrosis”) with the underlying disease aetiology (e.g. Perthes’ disease). Indications recorded as “other” were recoded when this was possible using the free text fields . Appendix I illustrates the recoding process for THA indications and Appendix II for revision.

The surgeon variables were the total number of very young adult (aged ≤ 20) THAs and the overall number of THAs recorded within the NJR. Very young THA frequency was categorized *a priori* as < 5 and ≥ 5 cases and overall frequency as < 100 and > 100 cases. A sensitivity analysis was undertaken using < 2 as the young THA threshold, which achieved the maximal AUROC when bivariate logistic regression models were fitted using each potential volume threshold in sequence.

The outcomes available from the NJR were “unrevised”, “revised”, and “death” together with a separate “time to event” (i.e. outcome or censorship) variable. The primary outcome was revision,

although we also presented mortality data. Patients that did not die or undergo THA revision were censored on 8th March 2017.

Although patient reported outcome measure (PROM) data is included within the NJR, this was only available for a very small proportion of our cohort but might be of greater relevance to future studies in this population. Similarly, at the time of conducting this study patient-level contemporaneous linked Hospital Episode Statistics (HES) data was not readily available from NHS-Digital for this cohort. However, a “sense check” of case numbers was undertaken using aggregate data from HES using Vantage, which is a commercial health analytics platform provided by Health iQ Ltd (London, UK). This query included the financial years 2014/15 to 2016/17 and used OPCS-4 codes recommended by the NJR for identifying primary hip arthroplasty cases(27). The complete list of OPCS-4 codes is provided in Appendix III.

Statistical analysis

Descriptive statistics and plots were used to illustrate temporal trends and survivorship. All analyses were reported at the level of the individual THA rather than individual patients and so both staged and simultaneous bilateral procedures were treated as independent events. However, we also undertook a sensitivity analysis using individual patients as the unit of analysis and so excluding second THA procedures in the same patient. Operations performed in 2017 were excluded from analyses of temporal trends as that year was incomplete.

Kaplan-Meier estimates of cumulative implant survival were plotted together with 95% confidence intervals and subgroups compared using logrank tests. The small number of events (i.e. revisions) within this cohort meant that it was not meaningful to use advanced techniques, such as Cox proportional hazards modeling.

All statistical analyses were undertaken using StataIC 15.0 (College Station, TX, USA). The protocol was approved by the NJR Research Committee and did not require separate Research Ethics Committee approval as only non-identifiable patient data was used.(28) Potentially disclosive cells (i.e. those reporting <5 individual patients) were suppressed or amalgamated in accordance with the NJR data sharing agreement. Suppressed values are described throughout the manuscript as “<5”.

Results

There were 769 arthroplasty procedures in 703 patients (i.e. 66 bilateral THA procedures, although not necessarily in a single sitting) recorded in the NJR between 1st April 2003 and 8th March 2017. The Vantage query identified 210 cases in HES between 2014/15 and 2016/17, which was comparable to the 206 cases extracted from the NJR for our cohort over the same time period. The median follow-up period (until death, revision, or censorship) was 5.1 (interquartile range [IQR] 2.6-7.8) years with 4,190 person-years available for follow-up across the cohort.

The median patient age was 18 (IQR 17-20, see Figure 1) with 56% of cases performed in female patients. Median body mass index (BMI) was 24kg/m² (IQR 21-28kg/m²), although this was only available in 42% of cases. Over the course of the study period, eight patients (each representing a single operative case) died, which resulted in an overall mortality rate of 1.9 per 1000 person-years. There were no deaths within 6 months of THA and there was no apparent association with operative indication. Thirty-five THAs had been revised at a median follow-up of 5.1 years, which produced a Kaplan-Meier survivorship estimate of 96% (95% confidence interval [CI] 94-98%) at 5 years.

The most frequent indications for THA were recorded as osteonecrosis (158 cases, 21%) and osteoarthritis (OA) (155, 20%). The other recorded indications were dysplasia (144, 19%), inflammatory arthritis (120, 16%), Perthes' disease (31, 4%), infection (21, 3%), slipped capital femoral epiphysis (20, 3%), surgery (13, 2%), trauma (6, 1%), and cancer (<5, <1%). The number of THAs for inflammatory arthritis fell gradually from a high in 2005 until 2009; after which there were

no further cases recorded in the NJR. A proportion of cases (120, 15.6%) did not have a clear indication recorded within the dataset.

There were 451 uncemented THAs (59%), 73 cemented (10%), 147 THAs recorded as “other, e.g. hybrid procedures” (19%), and 88 hip resurfacings (10%). Ten operations were unspecified (1%). The most frequent bearing combination was ceramic-on-ceramic (CoC, 438 cases, 57%) followed by ceramic-on-polyethylene (CoP, 116, 15%), metal-on-polyethylene (MoP, 68, 9%), and metal-on-metal (MoM, 30, 4%). There were 88 cases of resurfacing arthroplasty (11%).

The proportion of failures was highest in the MoM group (7/30, 23%) followed by resurfacings (10/86, 13%), MoP (5/67, 8%), CoP (<5/114, <4%), and CoC (10/436, 2%). These yielded Kaplan-Meier survival estimates for MoM (86%, 95% CI 66-94%), resurfacings (94%, 86-98%), MoP (93%, 80-98%), CoP (99%, 94-99%), and CoC (98%, 95-99%) at 5 years.

The most frequent indications for revision were loosening (7/35, 20%), infection (7/35, 20%), wear (6/35, 17%), and pain (5/35, 14%). The remaining causes (surgical error, periprosthetic fracture, dislocation, and “other”) all occurred in small numbers (<5) and cannot be reported under the terms of the data agreement. Similarly, the causes of failure in each bearing group would be potentially disclosive given the small numbers. However, Table 1 illustrates the bearings that were over-represented in each failure category.

Two hundred and forty two different surgeons were identified as the lead surgeon for THAs in this cohort. The lead surgeon was named as the primary consultant in 726 (94%) cases.

Temporal trends

Longitudinal trends demonstrated an annual increase in THA reporting within the ≤ 20 age group, with 14 cases in 2003 rising to 77 in 2009 before appearing to stabilize. However, the overall number

of cases captured by the NJR increased similarly over the same time period (Figure 2). The proportion of young THAs within the NJR increased from 0.05% in 2003 to 0.11% in 2009 before stabilising.

Trends in procedure type over time show an increase in uncemented THA at the same time as a decrease in cemented THA. A rise in hybrid procedures accounting for a decrease in both fully cemented and uncemented cases since 2013 (Figure 3).

Figure 4 shows that there has been a large increase in the number of CoC bearings since the inception of the NJR. This began to fall in 2012 in favour of CoP bearings. Resurfacing arthroplasty was also increasing until 2008 when this procedure began to fall. Metal-on-metal (MoM) bearings were becoming more popular until 2008 when they went into decline and disappeared from this population in the NJR altogether in 2011.

Associations with outcome

Figure 5a suggests that THA undertaken by surgeons with a higher number of very young THAs (age <20) recorded in the NJR was associated with greater implant survival (log-rank test $p=0.030$). A sensitivity analysis was undertaken to test whether or not this finding was an artefact of the decision to use ≥ 5 as the threshold. The sensitivity analysis using >1 as the threshold revealed a similar pattern (Figure 5b). Almost half (49%) the patients within the cohort were operated by a surgeon that did not previously have a paediatric hip case recorded in the NJR and 83% were operated by a surgeon with <5 cases recorded. Overall frequency of THAs in the NJR (i.e. all ages) using a threshold of ≥ 100 cases was not associated with very young THA survival (log-rank test $p=0.78$).

Figure 6 suggests that survivorship was significantly reduced for MoP, MoM, and resurfacing arthroplasty when compared with CoC and CoP (log-rank test $p=0.002$). Figure 7 shows that there was not a significant association between survivorship and type of cup fixation (log-rank test $p=0.06$). There was also no significant association with type of stem fixation (log-rank test $p=0.37$).

Kaplan-Meier survival estimates found no influence on overall survivorship by recorded indication (log-rank test $p=0.07$), surgical approach (log-rank test $p=0.80$) or age (<16 vs >16, log-rank test $p=0.14$).

Discussion

This study analysed data from the largest cohort ($n=769$) of THAs in very young patients that has been reported. It found good overall survivorship, a number of implant-specific associations with revision, and an association between implant survival and the number of very young THA cases that the operating surgeon had recorded within the NJR. The most frequently recorded indications for revision were infection (20%) and loosening (20%), although estimated survivorship in the cohort was high at 96% (95% confidence interval [CI] 94-98%) at 5 years.

Epidemiology and temporal trends

There was little change in the number of very young patients undergoing THA as a proportion of overall cases recorded in the National Joint Registry (NJR). Although the absolute numbers increased each year until 2009, this was in keeping with increased reporting of cases to the NJR over the same time period.

Most earlier studies have reported outcomes from patients undergoing cemented THA in the late 20th century for juvenile rheumatoid arthritis (RA). One consequence is that a recent meta-analysis identified RA as the most frequent indication for THA; accounting for 36.2% of procedures.(1) Our study found that only 16% of NJR cases had RA recorded as the indication, i.e. fewer than osteonecrosis (21%), osteoarthritis (20%), and dysplasia (19%). This discrepancy may reflect a publication bias towards RA in earlier case series or improvements in the medical management of RA. A population study from Sweden reported that the incidence of THA amongst RA patients fell from 12.6/1000 in 1998-2001 to 6.6/1000 in 2002-2006.(29) Our data is consistent with the finding

that RA is no longer a major indication for THA. However, it is possible that some RA cases were miscoded within the NJR and such trends are vulnerable to shifts in the classification criteria for juvenile arthritides(30).

Both metal-on-metal (MoM) bearing combination and hip resurfacing procedures declined sharply after 2008. Metal-on-metal bearings disappeared altogether from this cohort in 2011. This is likely related to high revision rates identified by implant registry data and safety concerns around metal wear debris.(31-33) DePuy recalled its Articular Surface Replacement MoM arthroplasty system in 2010.(34) Such concerns are particularly relevant to very young patients who have longer life-time exposure to potentially harmful metal debris, and who may become pregnant with the associated risks of high metal ion concentrations.(11) In our series, resurfacing arthroplasty was disproportionately represented amongst the implants requiring revision for “fracture” and is consistent with femoral neck fracture as a common indication for hip resurfacing revision.(35). There was a substantial increase in the number of uncemented and hybrid implants, which is consistent with the findings of earlier reports(1, 36) and overall trends across all age groups.(24)

Outcomes and associations with implant survival

When all-ages are considered within the NJR, primary THA has an overall mean 12-year revision rate of <5%.(24) However, these outcomes predominantly draw on the experience of older patients (mean age at THA of 69 years) who are likely to subject their implants to lower demands and are known to have a low lifetime risk of revision.(10) Early reports of THA survival in very young patients reported failure rates between 3 and 25%.(37) A Norwegian study of patients aged <20 years (n=132 hips) reported a 10-year revision rate of 30%. Our data (estimated 96% (95% confidence interval [CI] 94-98%) survivorship at 5 years) compares favourably with these earlier reports. This is consistent with evidence that revision rates for younger THA patients are lower in contemporary cohorts(1). Explanations that have been proposed for such improvements include improved biomaterials, greater use of uncemented implants, and fewer operations for RA, which were thought to be at

increased risk of failure.(1, 11, 38) This study should therefore reassure surgeons and patients that early reports of poor survivorship for THAs in very young patients might have been overstated.

This study did not find evidence that implant survival was associated with surgical approach, fixation type, or indication as recorded in the NJR. We did not observe an increased revision rate in RA patients that has been reported by other studies(6, 29), although this is possibly due to the small number of such cases (n=17).

There was evidence for reduced survival amongst implants with MoM and MoP bearings. The finding that MoM bearings are prone to early failure is also consistent with an established body of evidence(34, 39, 40), although our study was not designed to demonstrate causation and it is possible that our findings represent differences in underlying patient characteristics. Aseptic loosening due to wear debris is the most common mechanism of failure amongst ultra-high molecular weight polyethylene (UHMWPE) bearings and its incidence is inversely proportional to age.(41) It is possible that this trend may be mitigated in the future with increasing use of highly cross linked polyethylene [XLPE] as a bearing material.(42, 43) However, XLPE and UHMWPE implants are not distinguished separately in the NJR minimum dataset, and comparisons using the recorded component codes may be limited by different definitions of “XLPE” used between manufacturers(44). It was also not possible to distinguish loosening from failure of fixation, and thus it is possible that at least a proportion of the loosening cases may actually represent failure of fixation. We have therefore been unable to speculate as to whether this development has influenced outcomes.

A number of studies have reported an inverse association between surgeon volume and early revision surgery.(45-47) This is particularly important for surgeons performing THA in very young patients as our data suggest there might only be 60-80 such procedures per year in the whole of England, Wales, and Northern Ireland. One population study of older adults undergoing THA suggested that increased risk of early revision was associated with surgeons performing ≤ 35 cases

per year.(47) However, it has also been demonstrated that a surgeon’s experience (i.e. case volume) in specific patient subgroups, such as rheumatoid arthritis, is related to better outcomes that are independent of total case volume.(48) No previous study has explored associations between surgical experience and THA outcome in very young adults, which may be complicated due to the degree of deformity or the demands of the patient. Our data are consistent with the hypothesis that very young THA survival is reduced for surgeons that have performed fewer cases, although the observational nature of this study means we cannot determine whether or not there is a causal volume-outcome relationship. As case capture is incomplete, it is not possible to determine individual surgeon experience with certainty using historical NJR data. It is unlikely – given the small number of cases performed per year – that any study based in a single country will be able to state a volume threshold above which revision rates fall in very young patients undergoing THA.

Limitations

The NJR is a powerful tool for describing trends and monitoring survival given its large size and relatively high case capture rate. However, there are inherent limitations to drawing conclusions from observational data; even when the source is a well-designed clinical registry.(49) The main limitation for our data is that the median follow-up period was 5.1 years and it will clearly be necessary to continue reporting outcomes from this cohort. The three most frequently encountered indication categories were also either uninformative (e.g. “other”) or were more likely to be the outcome of an underlying aetiology. For example, “osteoarthritis” and “osteonecrosis” are more likely to represent the sequelae of diseases such as Perthes’ disease or Slipped Capital Femoral Epiphysis (SCFE). The indications available in the NJR minimum data set (MDS) forms have changed over time and certain indications have not been available for the entire period of the registry. Furthermore, these indications are selected by the responsible surgeon or their nominated deputy at the time of surgery and therefore inconsistencies in coding may be inevitable.

We did not have the component level data required to distinguish the different types of polyethylene used in bearings, however there are potential differences between the survival profiles of ultra-high molecular weight polyethylene (UHMWPE) and highly cross-linked polyethylene (XLPE).(42)

Case capture within the NJR is now at approximately 96%(25), which has increased gradually since it's inception in 2003 (43.4% 2003/4, 68.3% 2004/5, 81.6% 2005/6, 80.5%, 2006/7) until compliance reached 95.2% in 2007/8. Our search of unlinked HES records was consistent with high case capture among the population aged <20, although we could not access data from the early years of the NJR when the proportion of included cases was known to be lower. Future studies may seek to use linked NJR-HES data to shed further light on any systematic selection biases influencing the types of cases submitted during the early years of the NJR. It is likely that some surgeons contributing cases to the cohort gained experience of THA in the very young patient before the NJR was established. This meant that we could not infer a true volume-outcome relationship from the observation that implant survival was associated with the number of cases each surgeon contributed to the cohort. However, this might be interpreted as adding to the strength to the association, as the absence of earlier data is likely bias the data towards the null hypothesis (i.e. reducing the size of the effect).

This study relied on revision as its primary outcome and was unable to incorporate other outcomes that might be important to patients, such as pain, disability, and quality of life.(50) It is also possible that findings may be confounded by variables that are not collected by the NJR, such as patient activity levels or degree of deformity. For this reason, associations identified by such an observational study cannot be used to assume causal relationships. Nevertheless, the associations identified by this study are plausible (e.g. surgeon experience reported to the NJR) and/or have been reported by other sources (e.g. early MoM failure). The temporal trends described are likely to represent genuine changes in UK clinical practice over time.

This study provides strong evidence that reports of high implant failure from procedures undertaken during the last century may not be applicable to contemporary THA, with the overall survival for very young patients undergoing THA exceeding 96% over the subsequent five years.

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Figure legends

Figure 1: Age distribution of individuals within the cohort. *Six individuals with ages <13 were suppressed from the histogram to avoid presenting disclosive data.*

Figure 2: Annual number of primary THAs submitted to the NJR since its inception, with stratification for age group.

Figure 3: A graph illustrating temporal trends in the use of hip arthroplasty procedure.

Figure 4: A graph illustrating temporal trends in the use of bearing surfaces.

MoP – metal-on-polyethylene; CoP – ceramic-on-polyethylene; MoM – metal-on-metal; CoC – ceramic-on-ceramic.

Figure 5a: Kaplan-Meier plots showing THA survival by frequency of very young cases recorded in the NJR (<5 versus >5) with 95% confidence intervals.

Figure 5b: Kaplan-Meier plots showing THA survival by frequency of very young cases recorded in the NJR (1 versus >1) with 95% confidence intervals.

Figure 6: Kaplan-Meier plots showing THA survival by bearing surface with 95% confidence intervals. *MoP – metal-on-polyethylene; CoP – ceramic-on-polyethylene; MoM – metal-on-metal; CoC – ceramic-on-ceramic.*

Figure 7: Kaplan-Meier plots showing THA survival by type of fixation.

Table 1: Bearing surfaces disproportionately represented in each “failure” category										
	Loosening	Infection	Wear	Pain	Error	Other	Dislocation	Fracture	Mechanical failure	Total
Ceramic-on-ceramic	-	-	-	-	-	+	-	-	-	-
Ceramic-on-polyethylene	-	-	-	-	-	-	-	-	-	-
Metal-on-polyethylene	+	+	-	-	-	-	-	-	-	+
Metal-on-metal	+	-	+	+	+	-	-	-	-	+
Resurfacing	+	+	+	+	+	+	+	+	-	+

“+” indicates that a bearing was disproportionately represented in each failure category. “-” indicates that the bearing was appropriately or underrepresented. Absolute numbers in each category could not be presented to avoid breaching the data sharing agreement prohibition on potentially disclosive small cells. Confidence intervals were not used in creating this table given the very small numbers involved.