

Survivorship of Hip and Knee Implants in Pediatric and Young Adult Populations

Analysis of Registry and Published Data

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Background: One of the least researched areas in orthopaedic pediatrics is the safety and effectiveness of joint replacement, in part because it is uncommon and is undertaken for a wide range of conditions not common for adult joint replacement. This study used data from the AOANJRR (Australian Orthopaedic Association National Joint Replacement Registry) to analyze the use of total hip arthroplasty (THA) and total knee arthroplasty (TKA) in the pediatric population and to provide preliminary data on the outcome of these procedures.

Methods: The AOANJRR, which is part of the ICOR (International Consortium of Orthopaedic Registries), provided information on pediatric procedures reported to the registry by hospitals undertaking arthroplasty procedures in Australia. All THA and TKA procedures reported to the registry from 1999 to 2012 were included. The cumulative percent revision and the hazard ratio from Cox proportional-hazards models were used for analysis. All tests were two-tailed, with a 5% level of significance. Additionally, an overview of the literature is presented to provide a point of reference.

Results: Primary conventional THA was performed in 297 patients twenty years of age or younger; the cumulative percent revision at five years was 4.5%. Primary conventional THA was performed in 975 young adults twenty-one to thirty years of age; the cumulative percent revision at five years was 5.4%. Primary THA was performed in 105 patients twenty years of age or younger; the cumulative percent revision at five years was 4.6%. Primary TKA was performed in 159 young adults twenty-one to thirty years of age; the cumulative percent revision at five years was 10.3%.

Conclusions: Compared with older adults, pediatric patients and young adults undergoing THA and TKA have very different diagnoses, including a high prevalence of tumor. Although the reported rate of revision surgery is currently similar to that for older patients, the number of reported procedures and the follow-up period remain limited. It is important for registries to continue to collect and analyze data relevant to this cohort and to coordinate these activities in order to better understand the safety and effectiveness of joint arthroplasty in the pediatric population.

One of the least researched areas in pediatric orthopaedics is the safety and effectiveness of joint replacement. Joint replacement in this age group is relatively uncommon and is used to treat conditions that are not common reasons for adult joint replacement. Degenerative joint disease, in particular osteoarthritis, is the principal diagnosis responsible for almost 90% of primary total hip arthroplasties (THAs) and >90% of primary total knee arthroplasties (TKAs) in the adult population. In contrast, end-stage juvenile inflammatory arthritis, severe developmental dysplasia (developmental dislocation) of the hip, various causes of osteonecrosis, and tumors are some of the most common reasons for joint replacement in pediatric patients¹⁻⁷. The

treatment of severe articular and periarticular disease in young people is controversial, with many researchers advocating conservative therapies or alternative operative approaches while others recommend that joint replacement be considered depending on the diagnosis, degree of disability, and long-term outlook for the child⁵.

To our knowledge, the number of pediatric patients in the U.S. receiving joint replacement is unknown. Although uncommon, it is possible that a considerable number have undergone this surgery. It has been estimated that 10,000 to 30,000 patients less than twenty-five years of age have undergone joint replacement procedures in the last five years, and it is likely that many of those are pediatric patients⁸. It can also be

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TABLE I Overview of the Literature Focused on THA in Cohorts That Included Patients Younger Than Thirty-one Years of Age*

Authors	Year	No. of Patients/Hips	Revision Rate (%)	Mean Follow-up (yr)	Mean Age at Surgery (Range) (yr)	Most Common Stated Diagnoses
Roach and Paradies ¹⁵	1984	6/10	33.0	7.9	13.2 (9-16)	Arthritis
Ruddlesdin et al. ¹⁶	1986	42/75	14.0	5.4	14 (11-17)	JCA
Lachiewicz et al. ¹⁷	1986	34/62	3.0	6.0	26 (NR)	JRA
Learmonth et al. ¹⁸	1989	7/14	0	8.5	16 (12-22)	JCA
Witt et al. ¹⁹ †	1991	54/96	25.0	11.5	16.7 (NR)	JCA
Cage et al. ²⁰	1992	17/22	3.4	10.6	18.4 (14-20)	NR
Maric and Haynes ²¹	1993	17/17	7.7	9.3	18 (14-20)	NR
Hyder et al. ²²	1996	22/26	7.7	6.5	24 (17-30)	Perthes, PTA
Torchia et al. ¹³	1996	50/63	42.9	11.0	17 (11-19)	JRA, CD, trauma, tumors
Chmell et al. ¹⁴	1997	39/66	35.0	15.1	19.9 (11-29)	JRA
Kumar and Swann ²³	1998	16/25	12.0	4.5	24.9 (15-39)	SOD, JCA
Sochart and Porter ²⁴	1998	55/83	30.0	20.0	24.9 (17-29)	AS, CD, JRA, OA
Bessette et al. ²⁵	2003	11/15	33.0	13.6	16.5 (10-20)	NR
Dudkiewicz et al. ²⁶	2003	56/69	11.6	7.4	23.2 (14-29)	JRA, TA, DDH
Kitsoulis et al. ²⁷	2006	10/20	1.5	9.2	15.8 (13-24)	JCA
Restrepo et al. ²⁸	2008	25/35	3.0	6.6	17.6 (13.5-20)	AVN, JRA, DDH, SD, Perthes, OA, PTA, PRC
Wangen et al. ²⁹	2008	44/49	48.9	13	25 (15-30)	OA
Busch et al. ³⁰	2010	48/69	11.6	2.0	24.6 (16-29)	JRA, OFH
Clohisy et al. ⁵	2010	88/102	7.0	2.0	20.0 (12-25)	ON, OA
Girard et al. ³¹	2010	35/48	8.3	9.0	25 (15-30)	OFH
Finkbone et al. ³²	2012	19/24	4.0	2.4	16.4 (12-20)	AVN, JRA
Kamath et al. ³³	2012	18/21	5.5	4.1	18 (13-20)	CIO, SIO, SCD

*JCA = juvenile chronic arthritis, NR = not reported, JRA = juvenile rheumatoid arthritis, Perthes = Legg-Calvé-Perthes disease, PTA = post-traumatic arthritis, CD = congenital dysplasia, SOD = systemic onset disease, AS = ankylosing spondylitis, OA = osteoarthritis, TA = traumatic arthritis, DDH = developmental dislocation (dysplasia) of the hip, AVN = avascular necrosis, SD = spondyloepiphyseal dysplasia, PRC = pseudo rheumatoid chondrodysplasia, ON = osteonecrosis, OFH = osteonecrosis of femoral head, CIO = chemotherapy-induced osteonecrosis, SIO = steroid-induced osteonecrosis, and SCD = sickle cell disease. Note that some of the stated diagnoses (e.g., avascular necrosis and osteonecrosis) are equivalent. †Ruddlesdin et al. reported on twenty-nine of these cases in 1986.

anticipated that the rate of joint replacement in pediatric patients will increase, particularly given the popularity of this surgery and the incidence of diagnoses that may result in joint replacement surgery. Currently, over 294,000 individuals younger than twenty-one years of age are estimated to have juvenile arthritis⁹.

To our knowledge, the outcome of joint replacement in this age group is unknown. It is possible that such patients have more complications and earlier revision compared with the adult population, and there are several reasons for suspecting this to be the case. The surgery is potentially more difficult and more extensive at this age, and some of the diagnoses leading to joint replacement are likely to be associated with increased surgical risks⁶. Pediatric patients may require smaller, more complex, or customized implants, which may also be associated with an increased rate of early revision. Knowing the outcome of joint replacement surgery in this population is particularly important as many pediatric patients receiving joint replacement

can be expected to have a normal or nearly normal life expectancy. In adults, joint replacement is usually the final solution to the management of a degenerative joint. In pediatric patients, however, it is likely to be the first step in the life-long orthopaedic management of the affected joint, which will involve subsequent arthroplasty procedures on that joint. As repeated revision procedures are associated with increasingly less satisfactory outcomes, it is imperative that the aim of the first procedure be to obtain the best outcome possible in the clinical circumstance¹⁰.

The current literature is inadequate to determine outcomes. It consists of small case series with variable diagnoses and variable implants, making interpretation difficult¹⁰. Additionally, many of the studies do not refer to pediatric patients per se, but instead include young adults or middle-aged patients undergoing joint replacement who have a history of a pediatric condition such as juvenile arthritis that has led to either THA or TKA. In comparison with joint replacement surgery in the adult

population, there are evident gaps in our knowledge. Fundamental issues such as the choice of bearing surface and fixation have not been addressed¹¹. It is imperative that intermediate to long-term outcome studies be undertaken to determine the most effective treatment strategies in this population.

The low rate of joint replacement in pediatric patients means that it is difficult to obtain adequate numbers by means of a conventional study design. In contrast, registries are particularly effective at providing information on rare events. The present study made use of a national registry to determine the utilization of hip and knee replacement in the pediatric population and to provide preliminary data on the outcome of those procedures.

Materials and Methods

As part of the current series of ICOR (International Consortium of Orthopaedic Registries) projects, the AOANJRR (Australian Orthopaedic Association National Joint Replacement Registry) was asked to provide information on pediatric procedures reported to the registry. The AOANJRR commenced data collection in September 1999. Implementation was performed in a staged manner across the Australian states and territories, becoming fully national during 2002. Data are collected from all hospitals (both government and private) performing arthroplasty procedures. The AOANJRR has extensive validation processes, including use of a sequential multilevel matching process against health department unit data provided to the registry by each of the states and territories. Each hospital in Australia is required to report separation data to its relevant state or territory health department; separation data detail all admissions to hospitals, including the diagnosis and any procedures performed. Matching this to existing registry data enables the AOANJRR to identify the small number of unreported procedures. Following the retrieval of any unreported records and checking of mismatched data, the registry is able to obtain an almost complete and accurate data set relating to hip and knee arthroplasty in Australia.

The present study included all THA and TKA procedures reported to the registry up to the end of December 2012. The outcomes of patients younger than twenty-one years of age were compared with those of patients twenty-one to thirty, thirty-one to forty, and forty-one to fifty years of age. The principal outcome measure was the time to the first revision, assessed by means of both the number of

revisions per 100 observed component years and Kaplan-Meier estimates of survivorship.

The cumulative percent revision at a certain time (e.g., five years) is the complement of the Kaplan-Meier survivorship function at that time (expressed as a probability) multiplied by 100. This percentage accounts for right-censoring due to death and “closure” of the database at the time of analysis. Confidence intervals for the cumulative percent revision are unadjusted pointwise Greenwood estimates.

Hazard ratios (HRs) from Cox proportional-hazards models, adjusting for age and sex where appropriate, were used to compare revision rates. For each model, the assumption of proportional hazards was checked analytically. If the interaction between the predictor and the logarithm of the time since surgery was significant in the standard Cox model, then a time-varying model was estimated. In that model, time points were chosen iteratively until the assumption of proportionality was met, and the HR for each selected time period was then calculated. If we report an HR value without specifying the time period, the HR is over the entire follow-up period. A p value of 0.05 (two-sided) was considered significant.

Results

Hip Replacement

The AOANJRR identified 297 primary THAs performed in patients younger than twenty-one years of age during the study period. This represents 0.08% of all THA procedures reported during that time. Approximately 55% of the patients were female. Osteonecrosis (29% of procedures) and osteoarthritis (28%) were the most common diagnoses. However, 12% had various types of dysplasia and 15% had autoimmune arthritis reported as the primary diagnosis. An additional 9% involved treatment for a bone tumor. Conventional THA (85%) was the most frequently used procedure, followed by total hip resurfacing (9%). Cementless fixation was used in 69% of procedures, and hybrid fixation involving cementation of only the femoral component was used in 21%.

The cumulative percent revision at five years was 4.5% (95% CI [confidence interval], 2.2% to 8.9%) in patients younger than twenty-one years of age (Fig. 1). No sex difference

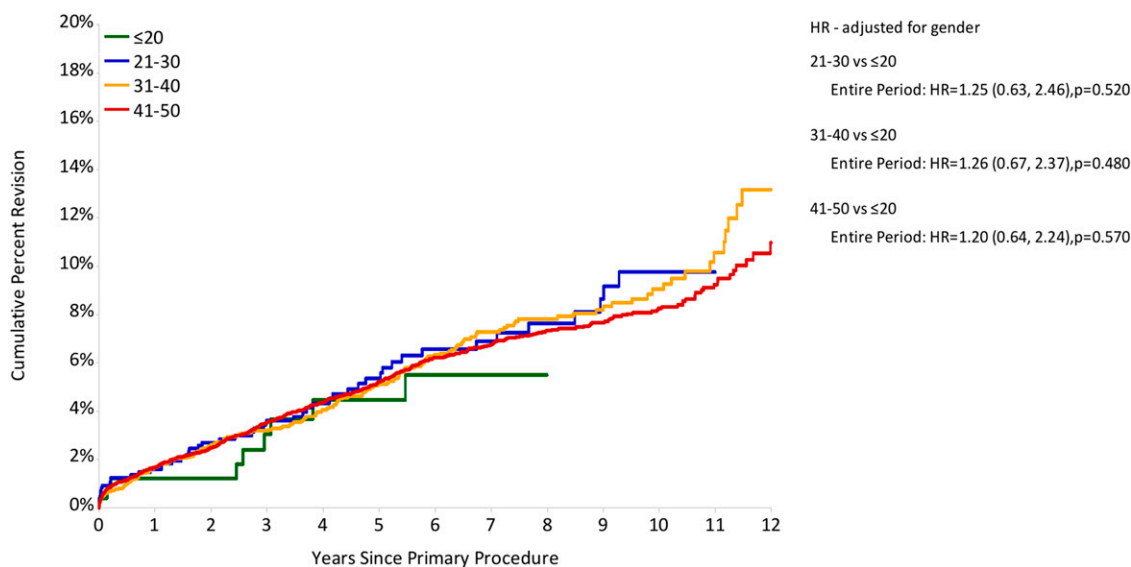


Fig. 1
Cumulative percent revision of primary conventional THAs according to age group (in years). The HRs (with 95% CIs) and p values for the comparisons between groups are also given.

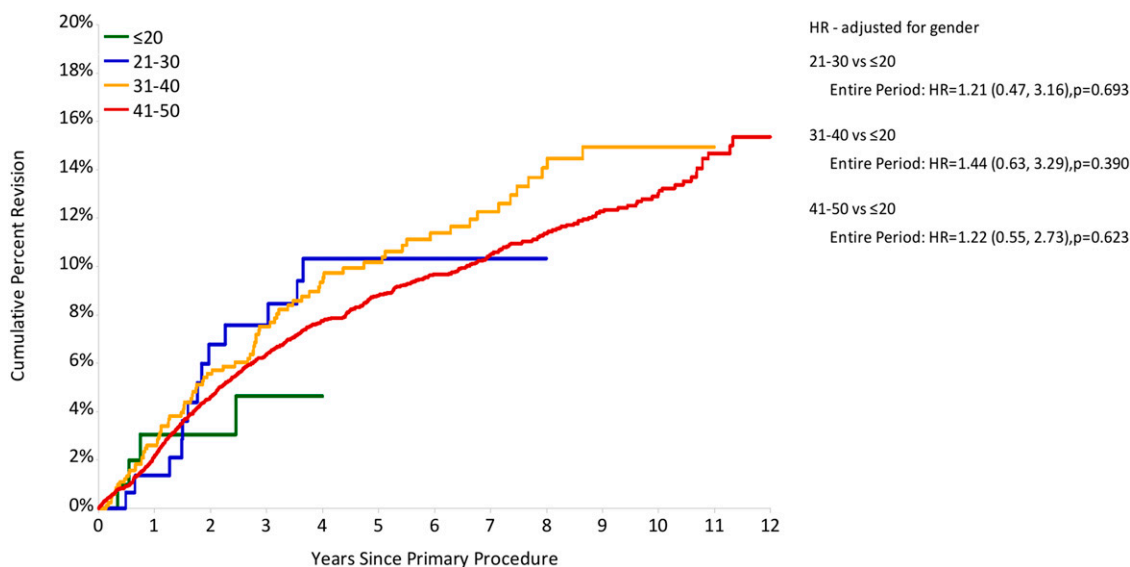


Fig. 2
Cumulative percent revision of primary conventional TKAs according to age group (in years). The HRs (with 95% CIs) and p values for the comparisons between groups are also given.

was observed. Twenty-eight of the procedures in this age group had involved hip resurfacing arthroplasty; one of these required revision at three years and eight months. Five-year mortality was significantly higher if the patient had a primary diagnosis of tumor (34%) compared with all other diagnoses (2%) (HR = 11.39, 95% CI = 2.98 to 45.5, $p < 0.001$).

A total of 975 conventional THA procedures were performed in patients twenty-one to thirty years of age. The cumulative percent revision at five years in this group was 5.4% (95% CI, 3.9% to 7.3%), which was higher than that in any of the other three age groups, although not significantly so (Fig. 1).

The most common bearing surface for conventional hip arthroplasty in patients younger than twenty-one years of age was ceramic-on-ceramic (40%), followed by metal-on-XLPE (cross-linked polyethylene) and metal-on-metal (22% each). Ceramic-on-XLPE bearings were less common (8%), and metal-on-conventional polyethylene was used in 4%. The number of revisions (ten) was too small to permit meaningful comparisons to determine the effect of the bearing surface.

One in every three revisions in patients younger than twenty-one years of age was caused by loosening and/or osteolysis, making this the most common cause for revision. Prosthesis dislocation and infection were the next most common causes, each causing 18% of revisions.

Knee Replacement

The AOANJRR identified 105 primary TKAs performed in patients younger than twenty-one years of age during the study period. This represents 0.025% of all TKA procedures reported during that time. Approximately 35% of these patients were female. The most common diagnosis was tumor (77%), followed by some form of juvenile arthritis (17%).

The cumulative percent revision at four years was 4.6% in this group (Fig. 2). No sex-related difference was observed. The overall five-year mortality rate was 35%. The most common bearing surface in this age group was metal-on-non-cross-linked polyethylene (98%).

A total of 159 primary TKAs were performed in patients twenty-one to thirty years of age; 55% of these patients were female. The cumulative percent revision at four years was 10.3% in this age group; after the first year, the rate was consistently four times higher in male than in female patients.

Fourteen revisions were performed in patients twenty-one to thirty years of age, with the most common reason being infection ($n = 6$).

Discussion

Current literature on pediatric patients is limited because of the small number of arthroplasty procedures performed in this age group. Most of the articles available include both pediatric patients and younger adults, as the frequency of arthroplasty procedures remains relatively low even in an expanded group of patients younger than fifty-five years of age¹². To evaluate the consistency of the results from the present study with the literature, we conducted a focused review of all available literature for arthroplasty patients younger than thirty years of age. We also included studies with a mixture of young adult and younger patients if the mean age did not exceed thirty-five years.

Literature on THA

Twenty-two studies with a total of 684 patients and 1011 THAs were identified by the literature search and reviewed; all of these studies included at least some patients younger than twenty-one years of age (Table I).

The main reasons for THA in the 684 patients were juvenile arthritis, developmental dysplasia of the hip (including

TABLE II Overview of the Literature Focused on TKA in Cohorts That Included Patients Younger Than Thirty-one Years of Age*

Authors	Year	No. of Patients/Knees	Revision Rate (%)	Mean Follow-up (yr)	Mean Age at Surgery (Range) (yr)	Most Common Stated Diagnoses
Sarokhan et al. ⁷	1983	17/29	14.0	5.9	23.0 (13-39)	JRA
Carmichael and Chaplin ³⁴	1986	13/25	0	5.1	7.2 (1-15)	JRA
Boublik et al. ³⁵	1993	14/22	4.5	3.9	26.0 (NR)	JRA
Parvizi et al. ³⁶	2003	13/25	16.0	10.7	17.0 (13-19)	JRA
Palmer et al. ⁴	2005	8/15	20.0	15.5	16.8 (NR)	JRA
Thomas et al. ³⁷	2005	10/17	0	6.0	22.4 (15-40)	JRA
Jolles and Bogoch ³⁸	2008	14/22	0	8.0	33.0 (15-42)	JRA
Malviya et al. ³	2010	20/34	41.5†	16.0	NR	JRA
Heyse et al. ⁶	2014	219/349	8.9	12.0	28.9 (11-58)	JRA

*JRA = juvenile rheumatoid arthritis, and NR = not reported. †Calculated from survivorship.

dislocation), and less commonly tumor, trauma, and spondyloepiphyseal dysplasia. The mean age at the time of surgery ranged from 13.2 to twenty-six years, and nine of the twenty-two reviewed studies included only patients younger than twenty-one years of age (Table I). All but one study reported the occurrence of revisions. The most common revision diagnosis was aseptic loosening of either the acetabular or the femoral component, with some reports of a higher incidence of acetabular loosening¹³. Other reasons for revision included prosthesis wear and femoral fracture. There was a general consensus that THA greatly decreased pain and greatly increased function in this population. However, some investigators found revision rates that led them to conclude that this procedure should be reserved for select patients in whom the benefits outweighed the risks^{13,14}.

Literature on TKA

Nine studies with a total of 328 patients and 538 TKAs were identified by the literature search and reviewed; eight of these included at least some patients younger than twenty-one years of age (Table II).

The main reason for TKA in the 328 patients was juvenile arthritis. The mean age ranged from 7.2 to 33.0 years. The most common reason for revision was infection; this was followed by loosening, which was thought to be due to a high activity level in these patients⁶. Additionally, stiffness was reported as a reason for revision in some patients. A small number of case studies indicated no revisions (Table II), and the follow-up duration in these studies was reasonable, suggesting that limited follow-up was not the reason. In most studies, mean range of motion improved, and quality of life likewise improved in the patients who regained mobility after the procedure.

Conclusions

Overall, the data from one of the largest national joint replacement registries in the world are consistent with the cur-

rent literature. The present study has, however, established that joint arthroplasty in the pediatric population is rare. Only eighty of every 100,000 hip replacements and twenty-five of every 100,000 knee replacements were performed in patients younger than twenty-one years of age. In addition, the Australian registry data have provided a more comprehensive overview of the use of hip and knee replacement in this patient group at a national level, including a more complete perspective on the reasons for the procedure, the types of procedures performed, and the types of prostheses used. Despite the small sample size, the outcomes indicate that both hip and knee arthroplasty in this patient population can yield results similar to those of the same procedures in adults twenty-one to fifty years of age.

There remains a clear need, however, for long-term studies with larger numbers of patients to enable surgeons and regulators to better understand the effectiveness and safety of hip and knee implants in pediatric patients and young adults. Pediatric patients and young adults without conditions that seriously limit their life expectancy are likely to have more active lifestyles and require repeated surgery to maintain joint function. There is no evidence regarding the effectiveness of repeated surgery in this age group. In order to improve the data regarding primary procedures and fill the gap in knowledge regarding the outcome of revision procedures, it is essential that registries and other larger data repositories continue to collect relevant data.

In conclusion, patients younger than twenty-one years of age and those twenty-one to thirty years of age who undergo hip and knee arthroplasty have very different diagnoses compared with older adults, including a high prevalence of tumor. Although the rate of revision surgery currently appears similar to that in older patients, the number of reported procedures and the follow-up duration remain limited. It is important for registries to continue to collect and analyze data relevant to this cohort and to coordinate these activities in order to better understand the safety and effectiveness of joint arthroplasty in the pediatric population. ■

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