Arthroplasty Today 7 (2021) 22–28

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

A Comparative Cohort Study With a 20-Year Age Gap: Hip Resurfacing in Patients Aged ≤35 Years and Patients Aged ≥55 Years

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ARTICLE INFO

Article history:
Received 15 June 2020
Received in revised form 14 October 2020
Accepted 1 November 2020
Available online xxx

Keywords:
Hip resurfacing arthroplasty
Implant survival
Patient demographic
Activity level

ABSTRACT

Background: This single-center retrospective cohort study aimed to evaluate and compare implant survival and patient-reported outcome measures in 2 distinct age groups separated by 20 years who underwent hip resurfacing arthroplasty (HRA).

Methods: Between 2005 and 2014, 2042 HRAs were performed by a single-surgeon, and 75 and 377 hips from patients aged ≤35 years and ≥55 years, respectively, were included in this study. Implant survival was determined for all available hips. Clinical features and patient-reported outcome measures were collected.

Results: Seven hips were revised, 4 for aseptic loosening of one or both components, one for infection, one for accelerated wear and metallosis, and one for femoral neck fracture. There was no difference in all-cause 10-year revision, with 97.1% (95% confidence interval 80.9 to 99.6) and 99.6% (95% confidence interval: 97 to 99.9) survivorship in younger and older patients, respectively ($P = .246$). Preoperatively, younger patients were less active than older patients on the Lower Extremity Activity Scale (LEAS) or University of California, Los Angeles, activity scale, but at follow-up, younger patients outpaced older ones.

Conclusion: Original to our study was the isolation and comparison of 2 distinct age groups. With excellent results in disparate age groups, HRA can be applied to a broad patient demographic and is suitable for those patients who want to achieve a high activity level as defined by Lower Extremity Activity Scale or University of California, Los Angeles, scores.

Introduction

Hip resurfacing arthroplasty (HRA) is a bone-conserving form of arthroplasty that uses a durable prosthesis that allows for the return to high activity levels [1-5], restores natural hip mechanics [6,7], and has lower dislocation rates relative to traditional total hip replacement (THR) [8]. HRA was initially intended as a stop-gap for young patients needing hip arthroplasty, by preserving the proximal femoral bone for a future THR [9,10]. Survivorship and outcomes exceeded expectations, and HRA is considered an optimal form of arthroplasty for young, active patients with healthy bone stock.

Studies have shown that the success of HRA is contingent upon a high-volume practice, strong surgical skills, implant brand, and careful patient selection [11-17]. Complications can easily arise if these qualifications are not met, and in recent years, HRA has become a more specialized procedure performed by select surgeons. Furthermore, given the known risks associated with HRA, identifying optimal patient populations ensures that the risks of HRA are minimized and that its benefits are maximized. Studies have demonstrated that the success of Registry data defines young patients as those aged ≤55 years to ≤60 years [18-22]. Expert consensus considers male candidates aged <65 years and female candidates aged <55 years ideal HRA candidates, when taken into account patient activity and bone quality.

Of note, both registry data and clinical trials have demonstrated higher revision rates in female candidates relative to their male counterparts [19,23]. Proposed underlying causes include smaller femoral head sizes, increased sensitivity to metal debris,

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https://doi.org/10.1016/j.artd.2020.11.006

dislocation, dysplasia, and aseptic loosening, with some studies showing that it is these factors rather than female sex that underlie the increased rates of revision observed [24,25]. In addition to increasing the rate of revision, a higher incidence of metallosis and corresponding adverse local tissue reactions have been reported in female candidates [26]. As such, many surgeons now consider female sex to be a contraindication to HRA. However, the etiology of higher revision rates in female candidates has yet to be fully clarified. Recently, a single-center study recently reported that developmental dysplasia and a contact patch to rim distance of ≤7 mm are the 2 primary causes of higher revision rates in female candidates [27]. As such, the benefit of excluding or including female patients in HRA has yet to be established.

There has also been a concern that outcomes in extremely young patients would not be equivalent to those of the ideal candidate [28]. The prevalence of hip osteoarthritis (OA) has globally increased in young adults with a steady rise since 1990 [29]. Young adults are increasingly participating in high-level sports, and studies have found associations between high levels of activity in youth, structural deformities, and premature OA. These patients are at risk for early onset OA and may subsequently need hip arthroplasty [30-35]. There is a paucity of studies reporting HRA outcomes in extremely young patients, with only few studies reporting revision rates and outcomes in patients aged ≤45 years [36-41].

Older patients, generally those aged ≥65 years, are not considered candidates for HRA because of low rates of revision and improved hip functioning after THR. Furthermore, a sedentary lifestyle and poor bone quality are thought to preclude older patients from HRA. In the case of the latter, older patients tend to be more susceptible to femoral neck fractures and aseptic loosening. Qualitative studies show that older adults have high expectations concerning physical health and level of activity. Recent studies have demonstrated low rates of revision and improved patient-reported outcome measures (PROMs) in older patients who underwent HRA [42,43].

Studies have compared HRA survivorship and outcomes in age-stratified cohorts using a binary cutoff. To the best of our knowledge, there has been no study specifically designed to compare a cohort of young patients to a significantly older cohort. A study that compares patients using a large age gap allows researchers to hone in on specific age groups and tease out disparities. Furthermore, excluding the mid-age range population from our cohort ensures that age differences will not be washed out. The purpose of the present study is to evaluate and compare the long-term survivorship of HRA procedures performed on extremely young patients, compared with a significantly older cohort, and to assess clinical findings and PROMs at ≥5 years of follow-up. The present study hypothesizes that survivorship from all-cause revision will be high in both groups with no difference according to age.

Material and methods

Selection criteria

This retrospective cohort study involved using a prospectively maintained, single-center, institutional registry to identify HRAs performed by a single surgeon. The institutional review board authorized this study, and per the study design, a waiver of consent was approved according to 45 Code of Federal Regulations 46.117(c) and a waiver of Health Insurance Portability and Accounability Act authorization in accordance with 45 Code of Federal Regulations 164.512(i). The setting of this study was the practice of a high-volume surgeon who routinely performs HRAs and treats active patients across a broad age range.

Between November 29, 2005 and February 14, 2014, 2042 primary HRAs were performed. At the time of surgical intervention, 75 hips (3.7%) were from patients aged ≤35 years, and 793 hips (38.8%) were from patients aged ≥55 years. While a registry was used to extract patient data, the database did not provide sufficient information to answer all research questions. Accordingly, chart review as required to obtain a comprehensive data set. In this study's setting chart, review was labor intensive requiring numerous hours per chart. This limitation was weighed against the importance of a large enough sample size to meaningfully address the study hypotheses. As such, all the younger patients were included, and the first 377 hips identified as being from older patients were included.

Patients underwent HRA if they had moderate to severe hip arthritis on radiograph or magnetic resonance imaging, hip pain interfering with daily activities, and failure of nonsurgical interventions (nonsteroidal anti-inflammatory drugs or physiotherapy). Plain radiographs were assessed for osteopenia and osteoporosis, and if there was a concern, a dual energy radiograph absorptiometry was recommended; T-score of ≤-2.5 was a cutoff. HRA was precluded in patients with known or suspected metal allergies, renal insufficiency, or pregnancy. Age was not an exclusion criterion, but older patients with sedentary lifestyles were largely referred for THR. Owing to its bone-conserving aspect, in younger patients, a sedentary lifestyle did not preclude patients from being referred to HRA. Patients who underwent HRA during the early years of the study were informed that risks associated with metal-on-metal (MOM) HRA were not yet fully understood. As more information became available, patients were informed that the primary risk associated with MOM-HRA was metal ion debris, which could lead to soft-tissue necrosis and early revision. Presurgery patients were offered both THR and HRA and encouraged to choose whichever form of arthroplasty they were most comfortable with in terms of risks and benefits. All patients were treated with HRA using the posterior approach.

The primary preoperative diagnosis was OA, found in 427 hips (94.5%). The Birmingham Hip Resurfacing (BHR; Smith & Nephew, Warwick, United Kingdom) was used in 448 hips (99.1%) and the Conserve Plus (Conserve; Wright Medical Technology, Arlington, TN) was used in 4 hips (0.9%). Postoperatively, patients received thromboembolic prophylaxis for 4 weeks and were allowed to weight-bear as tolerated with the use of assistive devices. No posterior hip precautions were administered, and postoperative pain control measures were administered on an individual basis.

The standard postoperative protocol included follow-up visits at 4 weeks, 3 months, and annually thereafter. At postoperative and yearly visits, anteroposterior pelvis and cross-table lateral radiographs were obtained. Baseline whole blood measurements of chromium and cobalt were obtained at the first annual postoperative visit, and follow-up laboratory work was conducted every 2 to 5 years, except in patients with elevated levels (>7 ppb/side) in which metal ion measurements were obtained every 6 to 12 months. Seven ppb is used as a clinical indicator for elevated levels because the Medicines and Healthcare products Regulatory Agency (MHRA) of the United Kingdom advocates 7 ppb for chromium and cobalt as a safe upper limit after HRA [44]. An upper limit of 14 ppb for chromium and cobalt is used for a patient with bilateral HRAs.

Patient assessment

Demographics, clinical features, radiographs, and functional measures were collected. Functional assessments included Harris Hip Scores (HHS), Hip Disability and Osteoarthritis Outcome Score for Joint Replacement, and the Lower Extremity Activity Scale (LEAS) or University of California, Los Angeles, (UCLA) activity scale.

For remote visits, the modified Harris Hip Score (mHHS) was used. Implant survival was determined by in-office visits or contacting patients via telephone or email.

Statistical analysis

Owing to censoring, implant survival at a minimum of 10 years was estimated in living patients using the Kaplan-Meier method with corresponding 95% confidence intervals (CIs). Survivorship was compared between the 2 age groups using a log-rank test. Demographics, clinical characteristics, and functional evaluations were assessed for normality, stratified by age, and then compared between cohorts using Wilcoxon rank-sum tests. Preoperative and follow-up PROMs at ≥5 years postoperative were compared using Wilcoxon signed-rank tests. Evaluation and comparison of follow-up variables were only performed in nonrevised, living patients. *P* value < .05 was considered significant. SAS software version 9.4 (SAS Institute Inc., Carey, NC) was used for statistical analyses.

Results

At the time of surgery, the median age of younger and older patients was 32.4 years (interquartile range [IQR], 28 to 33.9 years) and 62.6 years (IQR, 60.4 to 65.2 years), respectively. The majority of the cohort was comprised of male candidates, with no significant difference between the 2 age groups. Similarly, the 2 cohorts did not differ in body mass index. Surgical features, including median cup and head size, operative hip side, and bilateral vs unilateral HRA were not significantly different between the 2 age groups (Table 1).

Seven hips were revised, 4 for aseptic loosening of one or both components, one for infection, one for accelerated wear and metallosis, and one for femoral neck fracture. Six of the revised hips were from older patients, and the one revised hip from a younger patient was revised for aseptic loosening of oneor both components; all 7 hips had been implanted with BHRs. There was no significant difference in survivorship from all-cause revision in younger and older patients at 10 years, with survival curves of 97.1 (95% CI, 80.9 to 99.6) and 99.6% (95% CI, 97 to 99.9), respectively ($P = .246$; Fig. 1).

Postoperative complications included 5 dislocations in 3 patients, one case of deep vein thrombosis, and 3 cases of superficial wound infections; all occurred in patients from the older cohort. Six years after HRA, one hip from a male patient in the younger cohort experienced stem breakage and varus shifting. At the follow-up visit after 11 years, the implant was stable, and the hip was asymptomatic.

Median follow-up duration was 6.9 years (IQR, 5.6 to 8.7 years; max, 12.4 years) in the total cohort, excluding 2 patients with unilateral HRAs who died from comorbidities with their implants intact. A minimum of 5-year follow-up data were available in 405 (91.4%) hips from nonrevised, living patients.

Stratified by age, there was no difference between younger and older patients in chromium levels at both baseline and ≥5-year follow-up visit. The difference in baseline cobalt between the 2 cohorts approached significance, and at a ≥5-year follow-up visit, cobalt levels were significantly different in younger and older patients (Table 1). Follow-up chromium levels did not change from baseline in the total cohort ($P = .774$) and in younger and older patients ($P = .564$ and $P = .622$, respectively). Similarly, follow-up cobalt levels did not change from baseline in the total cohort ($P = .195$) and in younger and older patients ($P = .589$ and $P = .244$, respectively). Of note, 2 female patients and 4 male patients (n = 7 hips) had borderline elevated chromium or cobalt levels (>7 ppb/side) at ≥5-year follow-up visit. One patient was from the younger cohort, and 5 were from the older cohort; the minimum and maximum chromium or cobalt levels were of 6.7 ppb and 8.4 ppb, respectively.

PROMs, including HHS/mHHS, Hip Disability and Osteoarthritis Outcome Score for Joint Replacement, and LEAS or UCLA, significantly improved at follow-up in the total cohort and when stratified by age ($P < .0001$, for all measures). Preoperatively there was no difference in HHS/mHHS, but at follow-up, younger patients reported worse clinical functioning relative to older patients (Fig. 2). Younger patients lagged behind the older cohort on preoperative LEAS, but at follow-up, younger patients outperformed older patients (Fig. 3). Similar results were found when using preoperative and follow-up UCLA scores (Fig. 4). Detailed descriptions of PROMs in both cohorts are presented in Table 2.

Discussion

There is a general paucity of studies describing survivorship and outcomes in extremely young patients who underwent HRA. Excellent survivorship and improved PROMs have been reported in middle-aged and younger patients who underwent HRA [19-22,45-48]. In some studies, the population was stratified by a single age cutoff, generally around middle age, and thus, the youngest of the study cohort was not isolated. Recently, a large single-center study reported

Table 1
Demographic and clinical characteristics according to age at HRA.

Parameter	Total cohort	≤35 y old	≥55 y old	*P* value
n hips	452	75	377	
Median age, y (IQR)	61.7 (59.5 to 64.5)	32.4 (28 to 33.9)	62.6 (60.4 to 65.2)	<.0001[b]
Median body mass index, kg/m^2 (IQR)	26.2 (24.4 to 28.3)	26 (24.2 to 29.7)	26.1 (24.4 to 28.3)	.799
Patient sex, n (%)				
Male	395 (87.4)	68 (90.7)	327 (86.7)	.349
Side, n (%)				
Right	234 (51.8)	39 (52)	195 (51.7)	.965
Median acetabular shell, mm (IQR)	56 (54 to 58)	56 (54 to 58)	56 (54 to 58)	.334
Median femoral head, mm (IQR)	50 (48 to 52)	50 (48 to 52)	50 (48 to 52)	.194
Bilateral, n (%)	219 (48.5)	29 (38.7)	187 (49.6)	.174
Median baseline chromium, ppb (IQR)[a]	2.2 (1.5 to 3.5)	2.1 (1.5 to 3.7)	2.2 (1.5 to 3.5)	.891
Median baseline cobalt, ppb (IQR)[a]	1.8 (1.4 to 3)	1.6 (1.2 to 2.7)	2 (1.5 to 3.1)	.145
Median follow-up chromium, ppb (IQR)[a]	2.1 (1.5 to 3.1)	1.9 (1.4 to 3.6)	2.2 (1.5 to 3)	.679
Median follow-up cobalt, ppb (IQR)[a]	1.9 (1.3 to 2.6)	1.5 (1.2 to 1.9)	2 (1.4 to 2.7)	.0017[b]

HRA, hip resurfacing arthroplasty; IQR, interquartile range.
[a] Only nonrevised, living patients were included in follow-up or postoperative measurements.
[b] *P* value < .05 is considered significant.

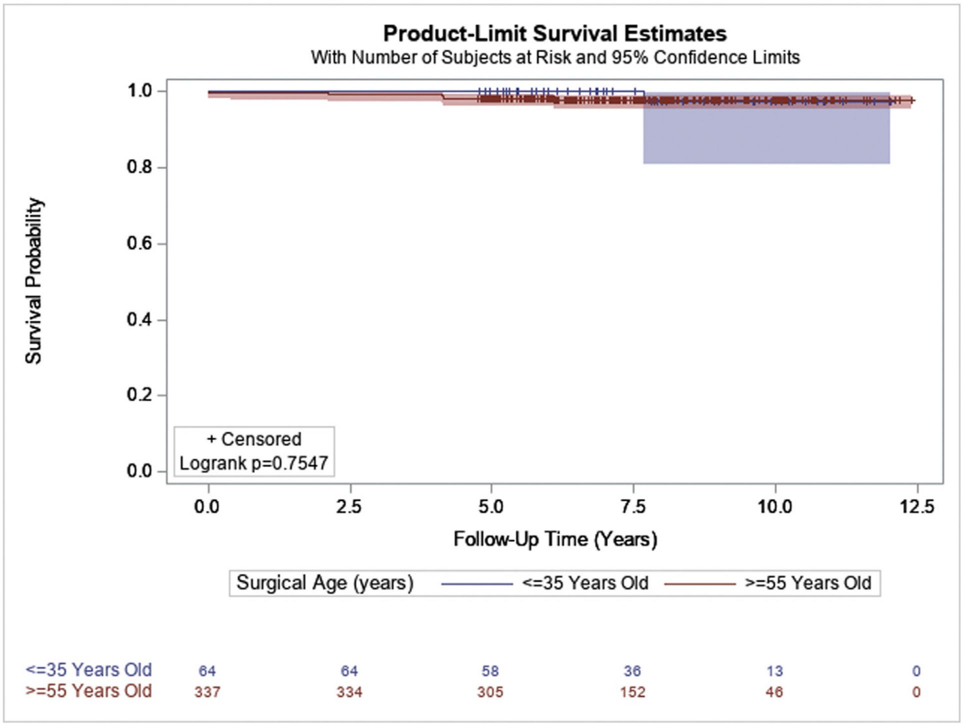

Figure 1. Kaplan-Meier plot of 10-y all-cause revision. Revision is compared between patients aged ≤35 y and patients aged ≥55 y. Shading indicates 95% confidence intervals for each cohort. *P* value is survival comparison using log-rank test.

HRA survivorship in patients aged ≤45 years (n = 217). Five- and 10-year survivorship was high at 94.6% and 93.8%, respectively. Postoperative PROMs improved, and a large percentage of the study population reported a return to high levels of activity including impact sports [36]. However, there was no comparison group, making it difficult to draw conclusions. In a small prospective study of HRA performed in 22 patients aged ≤30 years, early midterm survivorship was 100% with excellent radiographical results and overall

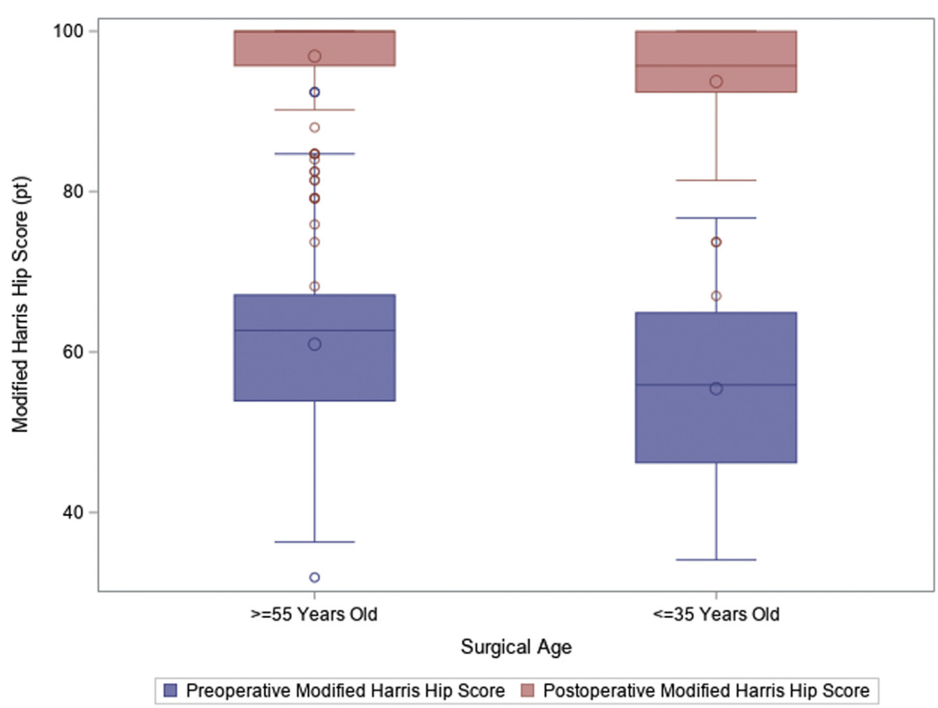

Figure 2. Box-and-whisker plots of the median (interquartile range [IQR]) preoperative and postoperative modified Harris Hip Score (mHHS) for the younger and older cohorts. Wilcoxon rank-sum tests were used to compare the 2 cohorts with no difference found between preoperative mHHS scores (*P* = .103). At follow-up, the younger patients had significantly lower scores (*P* = .0240).

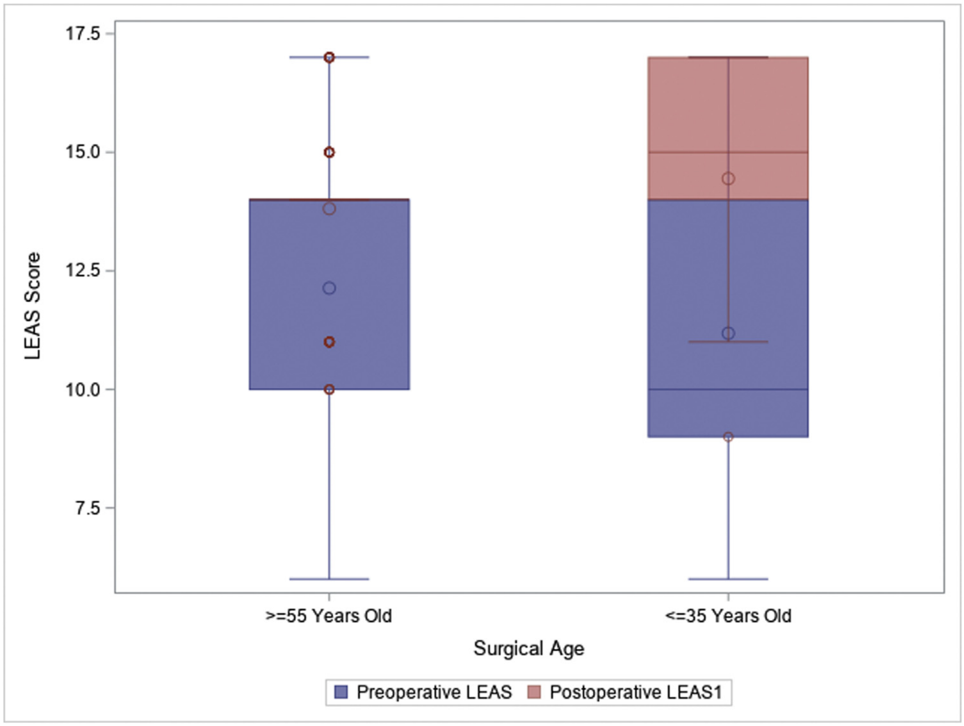

Figure 3. Box-and-whisker plots of the median (interquartile range [IQR]) preoperative and postoperative Lower Extremity Activity Scale (LEAS) for the younger and older cohorts. Wilcoxon rank-sum tests were used to compare the 2 cohorts with younger patients lagging behind the older cohort preoperatively ($P = .0013$). However, at follow-up, the younger patients outpaced the older cohort ($P = .0211$).

improvement in hip functioning [37]. Similarly, Beaulé et al. reported a 3% revision rate in a cohort of 83 patients aged ≤40 years who underwent HRA at a minimum follow-up of 2 years, with significant increases in postoperative UCLA scores [38].

Results from a study by Reito et al. [39], however, described a survivorship of 90.5% at 7 years in patients aged ≤40 years (n = 64). Of note, 6 of the 8 revised hips were implanted with the Articular Surface Replacement (DePuy, Warsaw, IN [no FDA approval]),

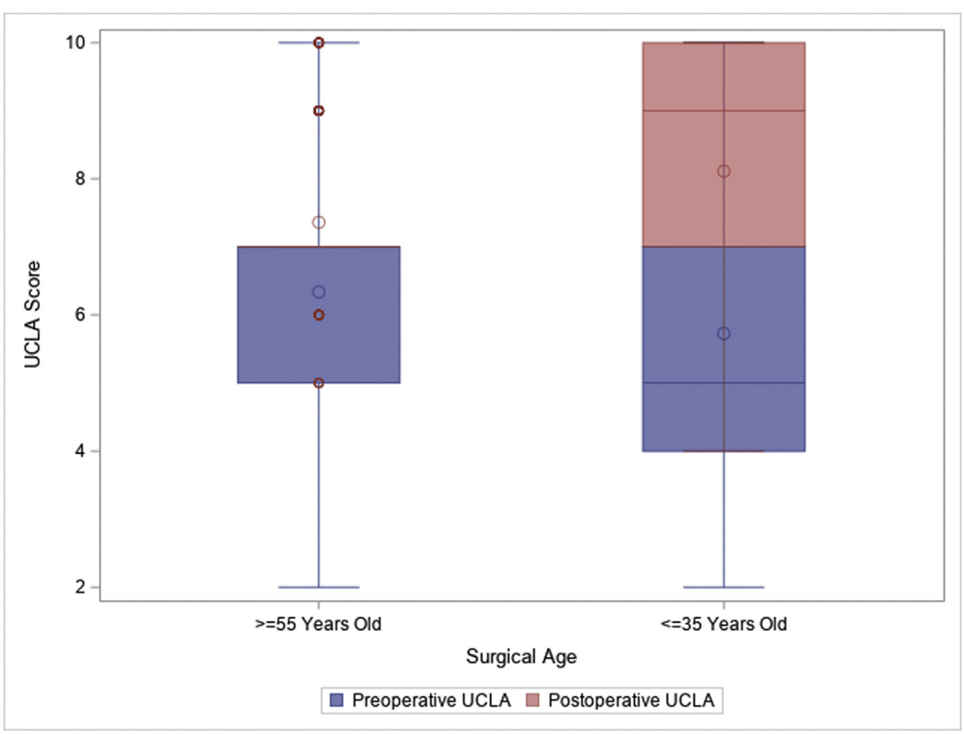

Figure 4. Box-and-whisker plots of the median (interquartile range [IQR]) preoperative and postoperative University of California, Los Angeles, (UCLA) for the younger and older cohorts. Wilcoxon rank-sum tests were used to compare the 2 cohorts with younger patients lagging behind the older cohort preoperatively ($P = .0013$). However, at follow-up, the younger patients outpaced the older cohort ($P = .0211$).

Table 2
Preoperative and postoperative patient-reported outcome measures according to age at HRA.

Parameter	Total cohort	≤35 y old	≥55 y old	*P* value
Median preoperative HHS, pts (IQR)	61.7 (51.7 to 67.1)	57.1 (46.2 to 64.9)	62 (53 to 67.1)	.103
Median follow-up HHS, pts (IQR)[a]	100 (95.7 to 100)	97.9 (93.5 to 100)	100 (95.7 to 100)	.0240[b]
Median preoperative LEAS, score (IQR)	11 (9 to 14)	10 (9 to 11)	11 (9 to 14)	.0013[b]
Median follow-up LEAS, score (IQR)[a]	14 (14 to 15)	15 (14 to 17)	14 (14 to 15)	.0211[b]
Median preoperative UCLA, score (IQR)	6 (4 to 7)	5 (4 to 6)	6 (4 to 7)	.0013[b]
Median follow-up UCLA, score (IQR)[a]	7 (7 to 9)	9 (7 to 10)	7 (7 to 9)	.0211[b]
Median preoperative HOOS JR, pts (IQR)	58.9 (53 to 67.5)	67.5 (51.4 to 70.4)	58.9 (53 to 67.5)	.141
Median follow-up HOOS JR, pts (IQR)[a]	100 (92.3 to 100)	100 (92.3 to 100)	100 (92.3 to 100)	.939

HHS, Harris Hip Scores; HOOS JR, Hip Disability and Osteoarthritis Outcome Score for Joint Replacement; HRA, hip resurfacing arthroplasty; IQR, interquartile range; LEAS, lower extremity activity scale; UCLA, University of California, Los Angeles.
[a] Only nonrevised, living patients were included in follow-up or postoperative measurements.
[b] *P* value < .05 is considered significant.

which was recalled from the market in 2010. Furthermore, proportionally, 22.2% of Articular Surface Replacement hips were revised, while 6.5% of BHR hips were revised. More than half of revised patients also had femoral head sizes ≤46 mm, which is a known risk factor for hip revision [39]. Similarly, Seyler et al. [40] reported a revision rate of 14% in patients aged <35 years (n = 70 hips) who underwent HRA with the Conserve, which was significantly higher relative to the rest of the study cohort (14% compared with 6%, $P = .008$). In univariate and multivariate modeling, age did not remain an independent risk factor, indicating that the relationship between age and revision may be confounded by other variables. The study was not designed specifically to evaluate survivorship in young patients who underwent HRA, which may also account for the study's findings [40].

The present study offers a unique view of survivorship, hip functioning, and level of activity in young and older patients. Unlike previous studies, which either reported results in younger or older patients or used a binary age cutoff, the present study compares findings between 2 distinct age cohorts representing younger and older patients separated by 20 years. Similar to studies describing HRA findings in single age cohorts at the extreme ends of the age spectrum, the youngest in our cohort was 14.9 years old, and the oldest of our cohort was 78 years old. Results were excellent in both patients aged ≤35 years and ≥55 years, with respective implant survivorships of 97.1% and 99.6% at 10 years after HRA. Hip functioning and level of activity improved after HRA across both age cohorts.

In the mid-age range population (generally defined as ≤55 years), including both female and male candidates, established 10-year survivorship from all-cause revision is approximately 96%-97%. Revision rates are contingent on the volume of the operating surgeon and implant brand used. When female candidates are excluded, survivorship generally jumps up to approximately 98%-99%. Comparatively, survivorship in both the younger and older cohorts were relatively similar to those in the mid-age range population. Approximately, 87.4% of the total cohort in the present study is male, with no significant difference in gender between the 2 age cohorts. It is questionable whether results from this study would be comparable to that of the ideal HRA candidate should the majority of our cohort be female.

Preoperatively, older patients reported a higher level of activity relative to younger patients. This was likely because of careful patient selection, in that only older patients with histories of and expectations for high levels of activity were included. At follow-up, both older and younger patients reported improved levels of activity relative to preoperative, but as expected, younger patients reported higher activity levels. At the most recent follow-up visit, younger patients reported lower levels of hip functioning relative to older patients. This finding may be due to different expectations in terms of pain and functioning across age groups, with older patients more likely to attribute discomfort and decreases in functioning to the aging process rather than the hip implant.

Of note, 1.5% of hips from nonrevised, living patients had borderline elevated chromium or cobalt levels (range, 6.7-8.4 ppb) at ≥5 years postoperatively. Stratified by age, 1.5% (one hip) and 1.7% (5 hips) were from the younger and older cohorts, respectively. Interestingly, the 2 female patients (3 hips) and 4 male patients (4 hips) with elevated metal ion levels represent 5.9% and 1.1% of nonrevised, living patients, respectively. The sample size (7 hips) was too small to ascertain whether the differences in age and sex were statistically significant. However, even without statistical analysis, it can be surmised that the sex distribution is likely related to underlying differences in metal sensitivity between male and female patients [49].

In our clinical practice, patients with elevated metal ion levels undergo more intense clinical observation. Every 6 months to 1 year, a metal artifact reduction sequence-MRI is obtained to evaluate soft tissues. In addition, every 6 months, metal ion testing and clinical examinations are performed. The surgeon and patient review these findings and decide on an individual basis whether or not revision is warranted.

Moreover, before surgery, the surgeon and patient discuss the risks related to metal ion debris generated from a MOM-HRA. These risks do not only include the potential for early revision but also the more rigorous clinical observation required for patients who undergo MOM-HRA. THR is offered as a viable option, and the benefits related to avoiding a MOM-HRA are explored. Ultimately, the surgeon provides information and a recommendation in terms of HRA or THR, but it is the patient who decides which risk-benefit ratio they prefer.

This study is limited by a number of factors. By design, the present study is retrospective which has inherent biases, some of which were addressed by prospectively collecting follow-up data. Although larger than reported to date, the sample size of young patients was relatively small, and as such, the CI for survivorship was moderately wide. The study was a single-center study with one fellowship trained surgeon who has performed numerous HRAs. Thus, the external validity of the study is limited. However, studies from surgeons with similar surgical experiences have described comparable findings. In addition, although every attempt was made to contact each patient, 8.6% of patients were lost to follow-up before a minimum of 5 years.

Conclusions

The success of HR across a wide age range of patients is explored in the present study, and our findings demonstrate that in the appropriate patient cohort, age is not indicative of implant survivorship and outcomes. Original to our study was the isolation and comparison of 2 distinct age groups. Long-term survivorship was greater than 95% across both cohorts, and while younger patients postoperatively outperformed older patients in activity level, both cohorts achieved high levels of physical activity and hip functioning. Given the present study's findings, future studies should attempt to compare survivorship and PROMS in young and older cohorts who underwent HR with their demographic counterpart who underwent THR. In conclusion, with excellent results in disparate age groups, HR can be applied to a broad patient demographic and is suitable for those patients who want to achieve a high activity level as defined by UCLA and LEAS scores.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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