What is the learning curve associated with a hip resurfacing?

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Abstract: There is a paucity of literature on the minimum number of cases necessary to become an expert surgeon in hip resurfacing arthroplasty (HRA). Thus, we aimed to describe (I) the learning curve of a primary hip replacement; (II) the learning curve of HRA using different end-points (complications, joint survival, component alignment and patient-reported outcome measures); and (III) what the minimum number of cases performed per year should be to maintain competency. A comprehensive literature search was performed reviewing joint arthroplasty registries, case-controlled studies, and case-series that have reported on the above. The reported learning curve necessary to decrease the overall complication rate in primary total hip arthroplasty (THA) is 90 cases. Additionally, the literature suggests that at least 35 primary THA cases per year is the recommended number above which complications reduce significantly. There is no doubt that only surgeons trained in primary hip replacement should perform HRA of the hip. On average, a learning curve of 50 cases has been described. Following this threshold, less complications, better radiographic assessment and superior patient reported outcomes have been described. It is the authors’ opinion that at least 25 cases should be performed annually, which is in line with other highly specialized surgical procedures.

Keywords: Learning curve; hip resurfacing; complications; total hip replacement

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Introduction

Modern hip resurfacing prosthetic systems have been in practice since the early 2000s (1). The indications of the appropriate patients have significantly evolved over the past decade (2). When compared to conventional total hip arthroplasty (THA), numerous benefits of hip resurfacing arthroplasty (HRA) have been portrayed, making it more suitable for the young and active patient: bone preservation at the femoral neck; maintenance of leg length; higher activity level; and great inherent stability provided by a large femoral head (3,4).

HRA has shown excellent clinical and radiographic outcomes at mid- to long-term follow-up (5,6). However, the outcomes of HRA have not been reproducible worldwide, and some registries have displayed substantially higher revision rates when compared to conventional primary hip replacement (7,8). Data from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) suggested that risk factors for revision of HRA were older patients, female gender, small femoral head sizes (less than 50 mm), patients with hip dysplasia, and certain implant designs (9).

Nonetheless, it is critical to recognize that registries may analyze implant survival in diverse phases of their implementation. As Corten and MacDonald suggested,
registries may be biased since new implants and technologies are undoubtedly associated with a learning curve (7). Understanding the presence and implication of a learning curve can help place the findings of a study in a more pragmatic, clinical context (10). In this scenario, if clinical trials are to include surgeons on their learning curve, they will be additionally assessing the learning curve of the procedure itself (11).

There is no doubt that highly specialized orthopaedic surgeries have a learning curve; periacetabular osteotomy (PAO) and hip arthroscopy constitute 2 non-arthroplasty examples for hip surgeons to understand expectations when beginning to perform these procedures, especially when they were priorly trained to perform only joint replacements. In the late 1990s, Davey and Santore compared the first 35 with second 35 PAOs performed by a single surgeon, observing a substantial reduction in the major complication rate (from 17% to 2.9%) (12). In line with these findings, Peters et al. found a significant decrease in complications (30% vs. 2%) when comparing the first 30 with the second 53 PAOs done by a single surgeon who had been trained by one of the fathers of the procedure and also had done 4 cadaveric surgeries (13). Regarding hip arthroscopy, Konan et al. compared the first 30 with the following 70 prospectively followed operations and found a marked decrease in complications as well as in operative time both for the central and peripheral compartment (14). Similarly, a systematic review of the literature also shows a learning curve of 30 cases necessary to reduce operative time and complication rates (15).

The number of resurfacing procedures has significantly reduced according to the UK’s National Joint Registry (8% in 2011 to 0.6% in 2017) (16,17) and the AOANJRR (9% in 2005 to 6% in 2008) (9). The sharp reduction in number of resurfacing arthroplasties performed has a resultant detrimental effect on the number of surgeons being trained on the procedure.

A hip resurfacing procedure is typically undertaken by surgeons that have mastered the ability to perform a THA; as it is universally accepted as a more challenging hip arthroplasty procedure given that the bony surface to work with is more limited and preserved femoral neck and head partially obstructs the acetabulum similar to a revision. Thus, additional steps may be necessary to improve visibility that may affect vascularity (e.g., capsular/soft-tissue release) and/or pelvic position (i.e., cup orientation), which are intimately related to the choice of the surgical approach. Thus, surgical approach might be an independent, additional, critical factor when describing and establishing the different learning curves associated with any procedure and in particularly hip resurfacing (18). In this paper we aimed to provide an updated literature review on what the learning curve is in order to perform a surface arthroplasty of the hip. To do so, we aimed to describe (I) the learning curve of a primary hip replacement; (II) the learning curve of hip resurfacing using different end-points (complications, joint survival, component alignment and patient-reported outcome measures); and (III) what the minimum number of cases performed per year should be to maintain competency.

**Learning curve of a conventional total hip replacement**

A learning curve has been described for both cemented and cementless THA. After comparing the first 90 cases of cemented Charnley THA operated between 1969–1973 with a matched cohort of 90 cases operated between 1984–1989 with the same prosthesis, Salai et al. evidenced a marked decrease in duration of operation, blood loss, dislocation rate, deep infection, breakage of trochanteric wires and early loosening (19). Callaghan et al. analyzed the results of the first and second series of 50 porous-coated THAs (20). Together with a lower percentage of femoral fractures (4% vs. 0%), substantial improvement in achieving femoral canal filling and a more accurate acetabular cup angle were seen in the second 50 cases (20).

In order to maintain a low number of complications over time, the literature suggests that 35 cases per year of primary THAs is the optimal number above which complications significantly reduce (21,22). However, in addition to the minimum number performed per year for each surgeon, a volume effect of the treating center has been illustrated. In the early 70s, Adams et al. introduced the relationship between volume and outcome to the healthcare field (23). After analyzing data on coronary arteriography outcomes from 173 institutions, the authors found significantly lower complication rates in high-volume hospitals (23).

Likewise, it has been shown that surgical volume is undeniably related to short-term morbidity and mortality in primary and revision total joint arthroplasty (24). After analyzing 19,925 primary and 2,536 revision arthroplasties of the hip and knee, Lavernia et al. found that surgeons with a low volume of primary cases (<10 cases/year) had a significantly higher mortality rate (24%), higher costs, and increased average length of hospital stay (9.3 days) when...
compared to medium-volume (between 10 and 100 cases/year and high-volume surgeons (>100 cases/year) (24). Since complications were coded upon the ICD-9 codes (including not only periprosthetic but also urinary tract infections, for instance), their relative impact on outcome were not addressed by the current coding system. In a similar study of approximately 70,000 Medicare patients who underwent THA, those treated at high-volume centers (with >100 surgeries done per year) evidenced a significantly lower risk of death than patients treated at low-volume hospitals (with ≤10/yearly surgeries), showing a mortality rate of 0.7% and 1.3%, respectively (adjusted OR, 0.58; 95% CI, 0.38–0.89) (25). Moreover, when analyzing only cases of primary THA, surgeons performing more than 50 cases/year had a considerably lower risk of dislocation (dislocation rate, 1.5%) than surgeons performing 5 or less yearly (dislocation rate 4.2%) (25). In line with these findings, Hedlundh et al. described that the dislocation rate remains relatively constant after undertaking approximately 30 operations (26).

Volume has also been associated with patient-reported functional status and satisfaction. After adjusting for confounders, Katz et al. showed that patients who underwent surgery in low-volume centers (<13 procedures per year) had worse functional status at 3 years following primary and revision THA compared to those performed at high-volume centers (>100 cases per year) (27). Also, patients who underwent primary hip replacement in low-volume institutions were more prone to be dissatisfied compared with patients whose surgeries were performed in high-volume hospitals (27).

### Learning curve of a hip resurfacing

**Complications**

Nunley et al. evaluated the learning curve of HRA by comparing the number of early complications of the first 650 cases amongst 5 hip surgeons (28). All of the surgeons had prior experience in hip resurfacing surgery, having each done more than 100 Birmingham (Smith & Nephew, Memphis, Tennessee, USA) HRAs. The authors detected 13 major complications (2%) with 7 (1.1%) reoperations; the major complication rate was greater for the surgeons’ first 25 cases compared to the second 25 ones (5.6% versus 1.6%, P<0.002) (28). These major complications consisted of 3 femoral neck fractures; 5 dislocations (of which 2 were converted to THA); 3 nerve injuries (of which only one remained unresolved) and 1 acetabular component early loosening revised to a THA (28).

Berend et al. reported the outcomes of 73 hip resurfacings (64 patients) performed between 2006 and 2009, which represented 6% of all of the primary hip arthroplasty procedures performed by the two primary surgeons (29). Both surgeons had prior surgeon-to-surgeon visits and cadaveric training; and all procedures were performed via the modified direct lateral, abductor-splitting (anterolateral) approach, using the first Food and Drug Administration (FDA)-approved HRA (30), consisting of a cemented femoral component and a cementless acetabular shell [Birmingham Hip Resurfacing (BHR); Smith and Nephew, Memphis, TN, USA]. The authors stated that only 79% of cases reported good or excellent outcomes, with an overall failure rate of 8% at a mean of 33 months, including 2 deep infections, 2 femoral neck fractures, 1 femoral aseptic loosening and 1 acetabular aseptic loosening (29). Even though the authors made it clear it was the institution’s early experience with HRA, there was no comparison in the timeline between the initial cases and the last ones.

In a similar study, Marker et al. analyzed the complication rate of 550 prospectively-followed HRAs operated by a single surgeon (31). In order to determine the effect of a learning curve on the operative results, the outcomes were stratified into 11 consecutive cohorts of 50 patients each. The authors detected 14 (2.5%) femoral neck fractures, with the risk being 8 times higher in the first 69 cases, markedly decreasing to 0.4% after this point, implying the existence of a learning curve related to this specific complication (31). Shimmin et al. were unable to show that fractures and other intraoperative complications occurred more often at the beginning of the learning curve (32). After analyzing 3,497 BHRs (Smith and Nephew) operated by 89 surgeons via the posterior approach, the authors found only 50 (1.46%) femoral neck fractures at a mean of 15.4 weeks (32). However, after reviewing the first 100 hip resurfacings performed by two experienced surgeons, the same authors reported that there was a learning curve of 50 cases, since the first 50 ones showed significantly more notching of the femoral neck and mal-seating of both the femoral and acetabular components when compared to the second 50 ones (33).

There have been two studies reporting on early data from designer centers. Aulakh et al. performed a multicenter analysis of 5,000 HRAs operated by 139 surgeons from 37 different countries, using the BHR (34). Of the 139 surgeons, only 2 had been involved in the design and of the implant. Thus, the series was divided into...
2 groups: developer surgeons (n=2,391) and non-developer surgeons (n=2,144, with all surgeons having done at least 40 procedures) (34). There were 50 failures in developer group (97% survival, 13 neck fractures) and 104 (94% survival, 38 neck fractures, P=0.0025) failures in the non-developer group (34). Amstutz et al. reported a 94.4% survival at 2- to 6-year follow-up (average, 3.5 years) of the first 400 hips (355 patients) implanted with the Conserve Plus device (Wright Medical; Arlington, Tennessee, USA) (35). Twelve hips (3%) were revised to a conventional THA due to loosening (7 cases), femoral neck fracture (3 cases), recurrent subluxations (1 case), and deep infection (1 case); 75% of their complications occurred in the first 100 HRAs, suggesting that experience plays a major role in decreasing femoral neck fractures and other complications (35).

Data on the learning curve of HRA in Canadian academic centers has also been analyzed (36). The first fifty HRA cases of five high volume arthroplasty surgeons (more than 100 primary THAs yearly) with no prior training on HRA were reviewed. It was found that the overall reoperation rate was low (3.6%), with femoral neck fracture being the most common cause (1.6%) (36).

Component alignment

Witjes et al. reported on the first 40 HRAs implanted by a single-surgeon and decided to analyze the radiographic ‘learning curve’ by comparing postoperative digital templating, measuring 6 established radiographic parameters (femoral offset, body moment arm, abductor moment arm, cup angle, stem-shaft angle and equator angle between cup and femoral component—called cup head angle) in 4 chronological groups of 10 cases each (37). An optimal radiographic result was established only in the last cohort, with the first initial cohorts showing a relatively steep cup position and a stem position in the posterior 1/3 of the neck (37).

In Nunley et al.’s study, the capacity to avoid relative femoral component positioning in varus did not improve until reaching 100 cases (31% of varus alignment in the first 100 surgeries versus 14% in the second 50 cases; P<0.004) (28). Regarding acetabular component orientation, specifically inclination, surgeons’ first 50 cases showed a trend towards more vertical components (i.e., inclination greater than 45 degrees) when compared their subsequent 50 cases (28).

Conversely, O’Neill et al., after analyzing the first 50 HRA of 5 high-volume Canadian arthroplasty surgeons, found that there was no learning curve in order to obtain an appropriate radiological component alignment, consisting of 140°±5° for stem-shaft angle and an acetabular inclination of between 35° and 45° (36). The authors reported a mean neck-shaft angle of 139° (range, 122°–155°) and an average acetabular abduction angle of 46° (range, 34°–64°), without any differences with cases who suffered a femoral neck fracture (36).

After analyzing 100 cases, Benoît et al. specifically focused on the learning curve of HRA through the anterior approach by comparing the first 50 consecutive cases done via this approach (Hueter group) to the 50 last consecutive cases performed through the Ganz approach (Ganz group) (38), which was the standard approach in the early 2000s at the author’s institution (39). With no cups surpassing an inclination angle of 55°, 19 cases in the Hueter group were positioned in the range of 45° to 55°, compared to only 8 cases in the Ganz group (P=0.013). These 19 ‘vertical’ shells detected with the anterior approach were almost equally distributed along the timeline (with 10 vertical acetabular components in the first 25 cases and 9 in the second 25 cases; P>0.05). However, no significant differences in intraoperative and postoperative complications were found between both groups (39). Since the primary surgeon of this series already had experience with the anterior approach and hip resurfacing through other approaches, the true learning curve of anterior approach HRA might be under-reported, taking into account that learning curves are partly surgeon-dependent and greatly influenced by preceding surgical and educational experiences (40).

The impact of computer navigation on the accuracy of component orientation in HRA has also been studied. In a randomized controlled trial, Cobb et al. analyzed the radiological results of HRA in models with cam-type deformity treated with conventional instruments, imageless navigation, and computed tomography-based navigation (41). Thirty-two students of surgical technology, priorly instructed in HRA, were shown detailed plans of the desired operative outcome, considering that this surgery should be performed within ±10 degrees of the optimal angular orientation and ±6 mm of entry-point translation in 95% of hips (41). The authors concluded that, for novice surgeons, only computed tomography-based navigation was accurate at reproducing hip biomechanics when compared to conventional neck-based instrumentation and imageless navigation (41). Although speculative, this ascertainment may also be true for novice surgeons learning primary THA.
Similarly, Ganapathi et al. compared 51 consecutive HRAs performed using image-free computer navigation with 88 consecutive HRAs performed without navigation, finding no differences in the average native femoral neck-shaft angles and the planned stem-shaft angle (42). Surgeries were performed by 2 experienced surgeons who had performed more than 75 HRAs using the conventional technique before the publishing study and therefore it was presumed that they were over the learning curve for conventional HRA (42). However, there were 33 patients (38%) in the non-navigated group with a deviation greater than 5 degrees in contrast to none in the navigated group when comparing the difference between the postoperative stem-shaft angle and the planned stem-shaft angle (42). Considering that the current literature has significant limitations, there is no consistent evidence of the benefits of computer navigation on the learning curve of arthroplasty trainees (43). Furthermore, there is little data on the effect on navigation on cup orientation in HRA, which is arguably the most important aspect of component orientation.

**Patient reported outcome measures**

Su and Su retrospectively reviewed their first 820 consecutive HRAs performed between the years 2004 and 2009, with a minimum 2-year follow-up (44). Overall, the clinical outcomes significantly improved when comparing preoperative and postoperative values (Average Harris Hip Score improved from 61 to 96.5 postoperatively), reporting only 13 revisions (1.6%): 3 femoral neck fractures, 5 avascular osteonecrosis, 2 acetabular loosenings, and 3 advanced local tissue reactions (44). In this sense, no significant effect of a learning curve was noticed in this study, with a safe application of HRA.

**Maintaining competency**

The need to perform a minimum number of cases per year to maintain competency in executing a highly specialized procedure has been introduced in other surgical fields but not orthopedics. Using retrospective data from National Registries, it has been highlighted that the minimum number of gastrectomies an upper gastro-intestinal surgeon should perform per year is 8 to 14 (average: 10) (45,46). There is no such guideline in arthroplasty to-date. However, the question of what the optimal number of periprosthetic joint infection (PJI) revision cases a surgeon needs to perform per year in order to improve outcomes was recently addressed in the PJI consensus meeting. Even though evidence is limited, some data suggest that surgeons who more often treat PJI patients will have better results than lower volume arthroplasty surgeons (47); seemingly, the former ones work at institutions performing variable number of PJI revision cases (between 3 to 80 PJI cases) annually (48-50).

The minimum number of cases required for improved outcome in overall revision THA is also unknown. Data from the UK national joint registry showed that 80% of surgeons performing revision knee arthroplasty and 60% of surgeons performing revision THA undertook less than 10 cases per year (51). Additionally, it has been shown that not only volume, but also the degree to which a surgeon specializes in a specific surgery may be equally important in order to reduce postoperative morbidity and mortality (52).

Taking these ambiguous figures into consideration, the last International Consensus Meeting (ICM) on the prevention of total joint arthroplasty infections recommended minimum surgical volume of 25 cases per year for a surgeon to qualify as an expert in PJI (47).

**Conclusions**

Undoubtedly, there is a learning curve associated with HRA. The findings of this review is in line with the Sixth Advanced Hip Resurfacing Consensus Meeting Statement that it takes at least 50 hip resurfacing procedures to get past the learning curve (61% agreement) and, in order to qualify to start doing this surgery, 75.7% of the surgeons suggested a minimum number of 100 THAs per year (53). Data has shown that this procedure should preferably not be done in hospitals that perform less than 25 HRA cases per year (54), which is similar to what it has been suggested for other highly specialized Adult Reconstructive surgeries. Our review clearly identifies that the learning curve influences complication-rates, radiographic measures and outcome. There is little data on how modern training should take place with the current low number of cases performed annually. It is our opinion that surgeons interested in performing HRA of the hip, should spend at least 6-month training in a high-volume center and make the appropriate arrangements for a ‘surgeon-mentor’ to be present for the first few cases they perform in an independent setting. We also encourage novice surgeons to perform additional training with virtual and augmented reality since it has proven to improve the accuracy of component orientation (55).
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None

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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