

Radiographic Factors Associated With Failure of Revision Hip Arthroscopy



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Purpose: To identify clinical and radiographic factors associated with failure of revision hip arthroscopy (RHA). **Methods:** A database was used to identify patients who underwent primary hip arthroscopy and revision hip arthroscopy (RHA) from January 2007 to December 2017 for the indication of femoroacetabular impingement and failure of the index procedure, respectively. The primary outcome was defined as the change, or difference, in the preoperative to postoperative alpha angle between patients with successful RHA and those with failed RHA. Failure was defined as reoperation on the operative hip for any indication or a modified Harris Hip Score (mHHS) of less than 70 at the 1-year postoperative time point. All patients had a minimum of 2 years' follow-up from the date of revision hip surgery. Patients with a history of revision were divided into those with failed revisions and those with successful revisions. The inclusion criteria for failed revision included a history of subsequent revision surgery (or arthroplasty) or an mHHS of less than 70 at final follow-up. **Results:** The study included 26 patients, comprising 8 (31%) with failed RHA and 18 (69%) with successful revision. The failure group showed a significantly smaller decrease in the alpha angle with surgery, measured on the Dunn view, compared with the success group. When the preoperative alpha angle was held constant, each 1° increase in the difference between the preoperative and postoperative alpha angles achieved during surgery was associated with a 17% decrease in the odds of failure. Patients included in the success group had both a higher preoperative mHHS (44.2 ± 8.6 vs 34.7 ± 9.6) and a higher postoperative mHHS (83.2 ± 8.3 vs 62.3 ± 14.2) than patients with failed RHA. There was a statistically significant difference in the frequency of patients who achieved the patient acceptable symptomatic state of +74.0 between the failure (25%) and success (83%) groups; 88% of patients in the failure group met the minimal clinically important difference, whereas 100% of patients in the success group ($n = 18$) met it. **Conclusions:** Complete resection of cam lesions as determined by changes in the alpha angle, anterior offset, and head-neck ratio when measured on the Dunn 45° view correlates with positive clinical outcomes after RHA. **Level of Evidence:** III, Retrospective Comparative Study.

The utilization of hip arthroscopy in the United States has grown substantially over the past decade, with a 180% increase in surgical volume in the United States from 2008 to 2013.¹ This procedure's popularity is owed to the evidence that shows that

patients achieve substantial clinical improvement with relatively few complications.^{2,3} Typical indications for hip arthroscopy include chondral lesions, labral tears, and loose bodies in the setting of femoroacetabular impingement (FAI).⁴ Despite these largely positive outcomes, a notable subset of patients experience persistent or recurrent pain after primary hip arthroscopy.⁵

There is sparse literature describing the rate of revision hip arthroscopy (RHA) in the general population, although a recent meta-analysis by Harris et al.⁶ reported a reoperation rate of 6.8% after primary hip arthroscopy, with approximately 2.9% being converted to total hip arthroplasty. As this small but significant cohort of patients has increased in size, so too has the popularity and academic study of RHA. RHA is currently indicated for patients who require improvements in residual pain and/or functional outcomes after primary hip arthroscopy.⁷

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A recent systematic review by Sogbein et al.⁸ of 9,272 hips determined that the following factors were associated with poor outcomes of primary hip arthroscopy: female sex, increased lateral center-edge angle, treatment with labral debridement alone, increased Kellgren-Lawrence grade (>3), decreased joint space (≤ 2 mm), chondral defects, increased Tönnis grade (≥ 1), elevated body mass index (BMI), increased duration of preoperative symptoms (>8 months), and increased age. This same systematic review showed that male sex, lower BMI (<24.5), younger age, and Tönnis grade of 0, as well as preoperative pain relief from clinically diagnostic intra-articular injections about the hip, predicted positive outcomes.⁸

The investigation of predictive factors associated with RHA is of substantial clinical value because arthroscopy is a less invasive intervention that may be used to delay hip arthroplasty.⁹ Although there is a growing body of literature examining outcomes associated with RHA, there is a general paucity of studies attempting to associate radiographic findings with outcomes after RHA.

The purpose of this study, therefore, was to identify clinical and radiographic factors associated with failure of RHA. Our hypothesis was that individuals with a failed RHA would be more likely to display a smaller change in the alpha angle from preoperatively to postoperatively on radiographic imaging and to have worse preoperative patient-reported outcome (PRO) scores.

Methods

Patient Selection

This single-site, institutional review board–approved study was a retrospective comparative study conducted using data obtained from a single surgeon's (T.Y.) operative database. Patients in this database were prospectively enrolled and underwent procedures relating to hip arthroscopy from January 2007 to December 2017. Patients were included in the study if they underwent RHA, had a complete set of preoperative and intraoperative radiographs, had completed preoperative and postoperative PRO questionnaires (i.e., modified Harris Hip Score [mHHS] and Non-arthritic Hip Score [NAHS]), and had at least 2 years of follow-up.^{10,11} The exclusion criteria consisted of patients who did not have 2 years of follow-up after RHA and those with a history of hip dysplasia or borderline hip dysplasia, a connective tissue disorder or autoimmune disease, or pediatric hip pathology such as slipped capital femoral epiphysis. Patients aged less than 16 years were similarly excluded.

All patients underwent diagnostic assessments that included a focused history and physical examination as part of routine preoperative assessments for

arthroscopic hip surgery. Patients were evaluated by the senior author (T.Y.), who is a sports medicine fellowship–trained orthopaedic surgeon. Preoperative provocative testing was conducted with the Patrick test and anterior impingement test. If the result of either test was positive, radiographic images of the pelvis were obtained in the supine anteroposterior (AP), Dunn 45°, and Dunn 90° views. These radiographic views were repeated and analyzed using intraoperative fluoroscopy. Additionally, magnetic resonance (MR) imaging or MR arthrography was used for evaluation of labral tears or chondral pathology in all patients. Computed tomography was considered in patients in whom further delineation of the bony anatomy was required.

The senior author's indications for RHA included persistent pain in the affected hip, prior arthroscopic labral repair with at least 12 months of recovery time and adequate physical therapy after the index surgical procedure, signs of residual FAI, chondral lesions, and recurrent labral tears. These indications are consistent with those in the RHA literature.¹² In this study, all patients undergoing RHA underwent labral repair if the labrum exhibited recurrent labral tearing or if the acetabular rim needed to be exposed.

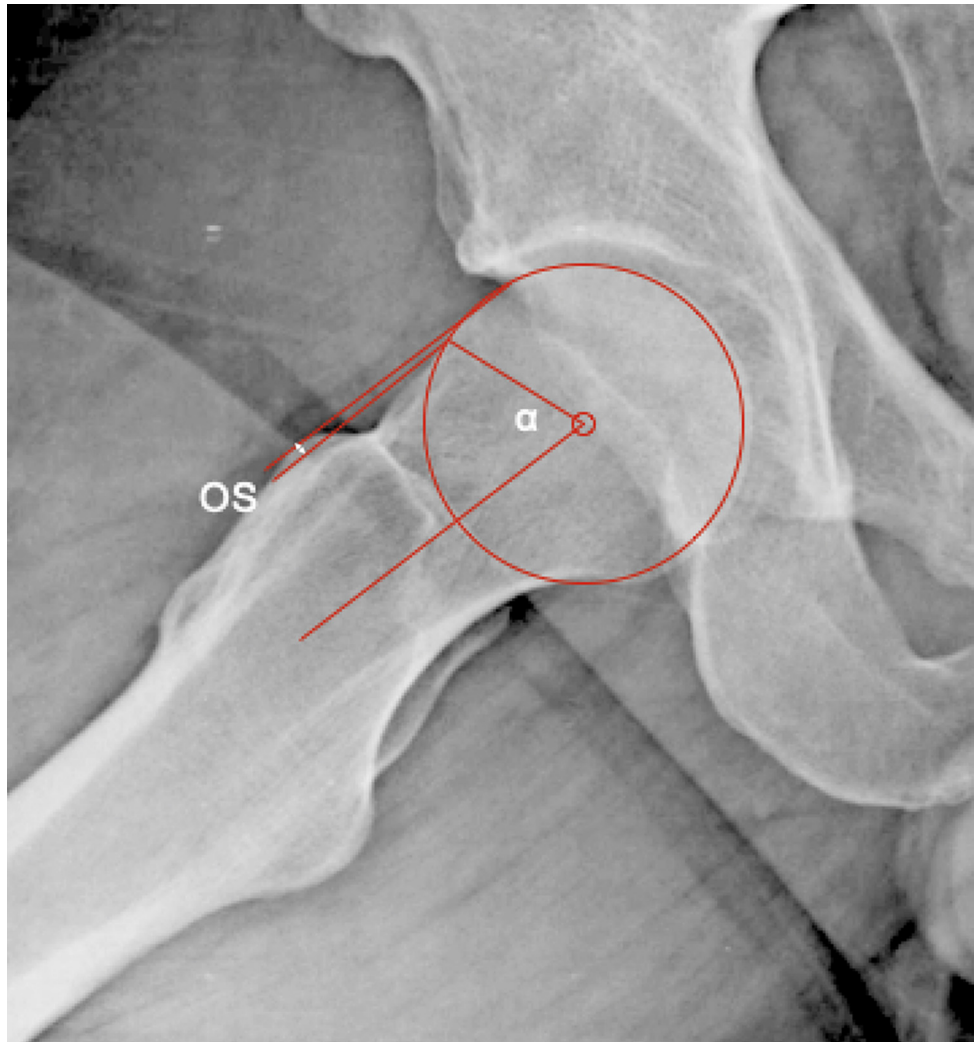
Radiographic evidence of FAI included an alpha angle of 60° or greater (on any view), a lateral center-edge angle of 40° or greater, and/or the presence of proximal focal acetabular retroversion (i.e., crossover sign) or focal chondrolabral delamination, shown on MR imaging or MR arthrography. In this study, the primary outcome was defined as the difference in the preoperative to postoperative alpha angle between patients with successful RHA and those with failed RHA. Failure was defined as reoperation on the operative hip for any indication or an mHHS of less than 70 at the 1-year postoperative time point, based on the study of Aprato et al.,¹³ who determined that patients with "fair" and "poor" outcomes had scores of less than 70 on the mHHS scale.

Radiographic measurements were taken by the senior author (T.Y.). The alpha angle was measured on each x-ray projection (AP, Dunn 45°, and frog lateral) (Fig 1). The head-neck offset ratio was similarly measured (Fig 2).

Demographic and Clinical Data

Patient demographic (age, sex, and BMI) and clinical (surgical information, laterality, and PRO scores) data were obtained via query of the surgical database. We used the mHHS and NAHS for our PROs. Patients were asked to fill out the mHHS and NAHS questionnaires at each postoperative visit. We used a minimal clinically important difference (MCID) of +8.0 and patient acceptable symptomatic state (PASS) of +74.0 to evaluate our postoperative outcomes for the improvement in the mHHS in RHA patients.^{2,3}

Fig 1. The femoral head contour is measured by placing a circle the best fits the circumference of the femoral head on a frog-leg lateral radiograph. A line in the center of the longitudinal axis of the femoral neck is drawn, and the alpha angle (α) is determined between a second line that extends from the center of the femoral head and where the femoral head loses its sphericity regarding the reference circle drawn. OS, offset.



Surgical Technique

The senior author (T.Y.) performed all RHAs with the patients under general anesthesia. The surgical procedures were conducted using standard midanterior and anterolateral portals. As part of the procedure, a comprehensive diagnostic survey was performed after horizontal interportal capsulotomy. Suture anchors were used to repair tears involving the base of the labrum at the chondrolabral junction. In this series of patients, all recurrent labral tears were repaired. No labral reconstructions were performed in this series of RHAs. Adhesions were excised and the capsule, if scarred to the labrum, was released with cautery. For chondral lesions, chondroplasty was performed with a shaver or thermal wand to stabilize chondral borders. Femoral osteochondroplasty was used to address any cam-type impingement. Acetabuloplasty and acetabular rim exposure were performed if there was persistent pincer-type impingement or prominence. The senior author then performed a dynamic

intraoperative examination to confirm adequate resection. The capsule was routinely repaired at the conclusion of the surgical procedure.

Postoperative Rehabilitation

All patients were given fitted postoperative hip braces that were applied immediately postoperatively to limit both hyperextension and external rotation for 1 week. They were restricted to flat-foot weight bearing on crutches for the first 4 weeks postoperatively. Per the senior author's protocol, patients were routinely prescribed cephalexin (500 mg, 4 times per day) for 3 days for infection prophylaxis, Celebrex (200 mg daily; Pfizer, New York, NY) for 14 days for heterotopic ossification prophylaxis, and aspirin (81 mg daily) for 7 days for deep venous thrombosis prophylaxis. Postoperative physical therapy was initiated 1 week after surgery and continued as needed until patients progressed to full participation in sports and activities.

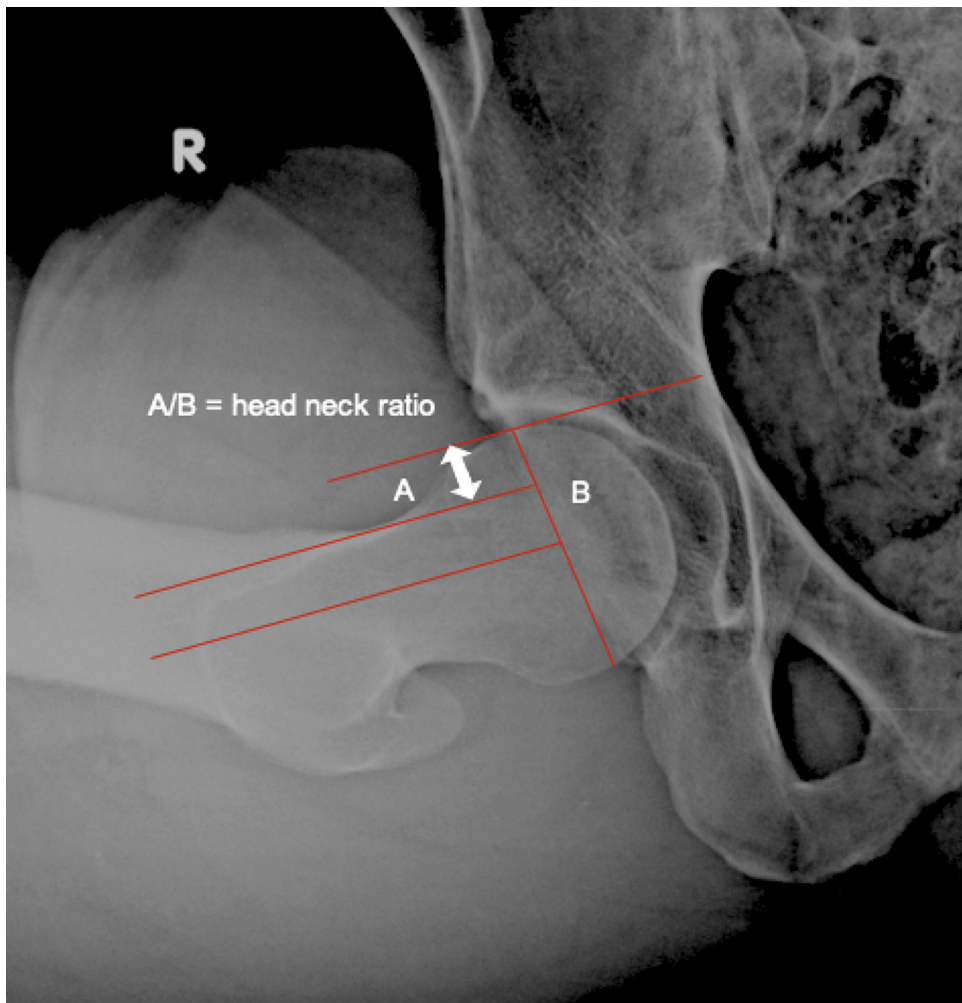


Fig 2. The head-neck offset is calculated by drawing a line along the axis of the femoral neck and drawing a second parallel line at the level of the anterior contour of the femoral neck. A third parallel line is drawn at the uppermost part of the femoral head; the widest section of the femoral head is then measured, and the difference is the head-neck offset value. The head-neck offset ratio is the smaller difference between these 2 lines divided by the larger difference. R, right side (leftover from XRAY); A, the distance between the axis of the femoral neck and a parallel line at the level of the anterior contour of the femoral neck; B, the widest section of the femoral head.

Statistical Analysis

Statistical analysis was performed using the R program (R Foundation for Statistical Computing, Vienna, Austria). We used the independent-samples *t* test to compare continuous variables between the 2 groups and the χ^2 test to compare differences between categorical variables such as injury mode, presence of the crossover sign, and presence of the ischial spine sign. Logistic regression was performed to evaluate the association between the change in the alpha angle with

surgery and the likelihood of failure after RHA. Statistical significance for all analyses was defined as $P < .05$.

Results

Of the 32 available patients, 26 (81%) met the inclusion criteria for this study (at ≥ 2 years postoperatively) and were included in the analysis. A total of 8 patients were classified as having failure, with 2 patients (25%) within the failure cohort undergoing RHA and the remaining 6 patients (75%) with failure reporting an mHHS of less than 70 at 2-year follow-up. Eighteen patients were included in the success group. There were no statistically significant differences in baseline characteristics between groups regarding age, sex, BMI, or laterality (Table 1).

There were no statistically significant differences with respect to preoperative radiographic parameters (Table 2). No statistically significant differences were observed between groups with respect to preoperative alpha angles across all 3 views, with $P > .05$ for all. Postoperatively, the failure group had a larger alpha

Table 1. Patient Demographic Data

Variable	Failure Group (n = 8)	Success Group (n = 18)	<i>P</i> Value
Age, yr	33.4 ± 12.4	38.8 ± 13.7	.35
Sex: female	5 (63)	10 (56)	>.99
Body mass index	26.5 ± 5.7	26.0 ± 4.8	.79
Procedure laterality: left	2 (25)	7 (39)	.67

NOTE. Data are shown as mean ± standard deviation or number of patients (percentage).

Table 2. Radiographic Data

Variable	Failure Group (n = 8)	Success Group (n = 18)	P Value for Group Comparison	Correlation	P Value for Correlation
Preoperative Tönnis grade (>0)	1 (13)	12 (67)	.04		
Preoperative crossover sign	3 (38)	4 (22)	.635		
Preoperative ischial spine sign	3 (38)	6 (33)	>.999		
Postoperative Tönnis grade (>0)	2 (25)	12 (67)	.09		
Preoperative alpha angle,					
Anteroposterior view	46.5 ± 4.1	52.7 ± 11.3	.153	0.953	<.001
Frog-leg view	43.5 ± 4.4	43.3 ± 7.6	.940	0.907	<.001
Dunn view	60.3 ± 5.8	62.5 ± 11.5	.619	0.990	<.001
Postoperative alpha angle,					
Anteroposterior view	47.6 ± 3.0	50.1 ± 9.9	.490	0.962	<.001
Frog-leg view	43.2 ± 4.0	40.9 ± 4.6	.230	0.786	<.001
Dunn view	54.2 ± 8.2	48.2 ± 5.2	.036*	0.928	<.001
△ Alpha angle,					
Anteroposterior view	1.1 ± 3.1	-2.5 ± 4.3	.047*		
Frog-leg view	-1.4 ± 3.3	-2.4 ± 6.1	.690		
Dunn view	-6.1 ± 3.9	-14.7 ± 10.3	.032*		
Offset data					
Preoperative anterior offset	3.7 ± 1.3	4.0 ± 1.9	.670	0.691	<.001
Postoperative anterior offset	5.4 ± 1.7	7.4 ± 1.8	.015*	0.950	<.001
△ Anterior offset	1.7 ± 1.1	3.4 ± 2.2	.043*		
Preoperative head-neck offset	0.09 ± 0.06	0.12 ± 0.16	.625	0.774	<.001
Postoperative head-neck offset	0.10 ± 0.03	0.14 ± 0.03	.012*	0.948	<.001
△ Head-neck offset	0.01 ± 0.07	0.02 ± 0.16	.883		

NOTE. Data are shown as mean ± standard deviation or number of patients (percentage) (achieved power).

*Statistically significant ($P < .04$).

angle as measured on the Dunn view relative to the success group ($54.2^\circ \pm 8.2^\circ$ vs $48.2^\circ \pm 5.2^\circ$, $P = .036$). The failure group showed a significantly smaller decrease in the alpha angle as measured on the Dunn view compared with the success group ($-6.1^\circ \pm 3.9^\circ$ vs $-14.7^\circ \pm 10.3^\circ$, $P = .032$). The failure group also showed a slight increase in the alpha angle as measured on the AP view, whereas the success group reported a slight decrease ($1.1^\circ \pm 3.1^\circ$ vs $-2.5^\circ \pm 4.3^\circ$, $P = .047$).

In addition, the failure group showed a significantly lower postoperative anterior offset than the success group ($5.4^\circ \pm 1.7^\circ$ vs $7.4^\circ \pm 1.8^\circ$, $P = .015$). The failure group showed a smaller increase in anterior offset with surgery compared with the success group, although this did not reach the level of significance ($1.7^\circ \pm 1.1^\circ$ vs

$3.4^\circ \pm 2.2^\circ$, $P = .043$). There was a statistically significant difference in the postoperative head-neck offset ratio between successful RHA and failed RHA (0.14 ± 0.03 vs 0.10 ± 0.03 , $P = .012$). Intraobserver reliability was calculated for this cohort and there was a high degree of agreement between reads ($P < .001$ for all measurements). The results of this analysis are shown in Table 2.

Patients included in the successful RHA cohort had both a higher preoperative mHHS (44.2 ± 8.6 vs 34.7 ± 9.6 , $P = .019$) and a higher postoperative mHHS (83.2 ± 8.3 vs 62.3 ± 14.2 , $P < .001$) than patients with failed RHA (Table 3). The change between preoperative and final follow-up mHHS values, however, was not significantly different. Both groups showed a high rate

Table 3. Patient-Reported Outcome Scores

Variable	Failure Group (n = 8)	Success Group (n = 18)	P Value
Preoperative mHHS	34.7 ± 9.6	44.2 ± 8.6	.019*
Postoperative mHHS	62.3 ± 14.2	83.2 ± 8.3	<.001*
△ mHHS	27.6 ± 22.1	39.0 ± 13.3	.114
MCID for mHHS	7 (88)	18 (100)	.308
PASS for mHHS	2 (25)	15 (83)	.008*
Preoperative NAHS	37.5 ± 7.6	51.5 ± 12.7	.008*
Postoperative NAHS	63.8 ± 21.0	87.4 ± 9.2	<.001*
△ NAHS	26.3 ± 23.0	35.9 ± 15.7	.224

NOTE. Data are shown as mean ± standard deviation or number of patients (percentage).

mHHS, modified Harris Hip Score; MCID, minimal clinically important difference; PASS, patient acceptable symptomatic state; NAHS, Non-arthritis Hip Score.

*Statistically significant ($P < .04$).

of patients who achieved the MCID of +8.0. However, there was a statistically significant difference in the frequency of patients who achieved the PASS of +74.0 between the failure and success groups (25% vs 83%, $P = .008$).

Furthermore, patients included in the failed RHA cohort had both a lower preoperative NAHS (37.5 ± 7.6 vs 51.5 ± 12.7 , $P = .008$) and a lower postoperative NAHS (63.8 ± 21.0 vs 87.4 ± 9.2 , $P < .001$) than patients with successful RHAs. The change in the preoperative to postoperative NAHS, however, was not significantly different.

On the basis of logistic regression, the change in the preoperative to postoperative alpha angle, as measured on the Dunn 45° view, was associated with the likelihood of failure of RHA when controlling for the effect of the preoperative alpha angle. When the preoperative alpha angle was held constant, each 1° increase in the change in the alpha angle with surgery (i.e., each 1° increase in the difference between the preoperative and postoperative alpha angles achieved during surgery) was associated with a 17% decrease in the odds of failure ($\beta = -0.185$ [95% confidence interval, -0.404 to -0.033]; odds ratio, 0.83; $P = .041$; McFadden pseudo $R^2 = 0.22$).

Complications

There were no short-term complications such as infection, deep venous thrombosis, or neurapraxia requiring medical intervention in all patients in both cohorts.

Discussion

The most important finding of this study was that the change in the alpha angle, anterior offset, and head-to-neck ratio were shown to be significantly associated with RHA failure in our cohort. The results of this study show an association between failure of RHA and the preoperative to postoperative change in the alpha angle, measured on the Dunn 45° view, when controlling for the effect of the preoperative alpha angle. We show that each 1° increase in the difference between the preoperative and postoperative alpha angles, measured on this view, is associated with a 17% decrease in the odds of failure (odds ratio, 0.83; $P = .041$). Similarly, the results of our study show that there is a smaller, statistically significant difference in the alpha angle (as measured on the Dunn 45° view) among patients with RHA failure as compared with those without RHA failure (-6.1° vs -14.7° , $P = .032$).

These results are clinically valuable, given that hip arthroscopy (both primary and revision) has become an increasingly popular procedure, with a significant increase in utilization across the United States over the past decade.¹⁴ Furthermore, the results of a meta-analysis by Harris et al.⁶ showed that there is an

increased reoperation rate after RHA relative to reoperation after the index procedure. They reported 14.6% of patients undergoing RHA (compared with 6.8%), with 5.9% of patients undergoing conversion to total hip arthroplasty (compared with 2.9%).⁶ With this increased morbidity from failed hip arthroscopy in mind, we sought to identify both clinical and radiographic associations of failure in the revision setting and to expand on the current body of literature investigating this topic.

Nho et al.¹⁵ showed that preoperative alpha angles on the AP and false-profile views were predictive of the mHHS and visual analog scale score at 2 years. Decreased femoral anteversion was also associated with failure, owing to inherent rotational deformity being the cause of impingement and not the typical mechanical impingement seen in most cases of FAI.¹⁶ These results appear to be consistent with our data on RHA; both lower preoperative patient-reported outcome measures (PROMs) and a decreased change in the alpha angle appear to be predictive of failure in RHA. A limitation of our study was that femoral version data were limited in our cohort. On a larger scale, a systematic review of 14 studies by de Sa et al.¹⁷ showed that correction of the preoperative alpha angle in cam-type FAI to a minimum of less than 55° leads to improved outcomes with respect to PRO scores, as well as superior range of motion postoperatively. This systematic review, however, did make note of the fact that the alpha angle is not standardized and that, although interobserver reliability is generally high for these measurements, it is not perfect.¹⁷ These conclusions echo our results. Although correction to less than 55° is certainly important, our data suggest that the change in the alpha angle can also be influential on outcome. Furthermore, because of potential error regarding interobserver reliability, the degree of change with the surgeon as a control may be more reliable than reference to an absolute number of 55°.

The changes in the alpha angle, anterior offset, and head-to-neck ratio were shown to be significantly associated with RHA failure in our cohort. These measurements were only significant, however, when the radiographs were evaluated in the Dunn 45° view. Although global evaluation of both the femoral- and acetabular-sided pathology is necessary, our results align with other findings that suggest the Dunn 45° view is especially important. In a recent study by Smith et al.,¹⁸ evaluation using the Dunn 45° radiograph was the most sensitive evaluation of cam morphology in patients undergoing hip arthroscopy for FAI. It is important to note that although the Dunn 45° view may be the most important view, a systematic evaluation of the femoral neck in multiple views intraoperatively is recommended in an attempt to completely address femoral-sided pathology, given that

inadequate resection of cam morphology is one of the leading causes of primary hip arthroscopy failure.

Several preoperative factors associated with clinical outcomes in primary hip arthroscopy have been previously identified. Lodhia et al.¹⁹ identified 8 preoperative patient factors that were associated with outcome, including age, duration of symptoms, BMI, preoperative mHHS, Hip Outcome Score—Activities of Daily Living (HOS-ADL), Hip Outcome Score—Sport-Specific Subscale (HOS-SSS), and visual analog scale score. Additionally, Domb et al.²⁰ identified the NAHS and mHHS, among other factors, as being predictive of outcome. Given the fact that previous literature has shown associations between inferior outcomes and inferior preoperative scores, it follows that the failure group's lower preoperative scores may have been predictive of their failure as well. Our study yielded similar results, given that we found that lower preoperative mHHS and NAHS values were significantly associated with worse outcomes postoperatively. Of note, there was no association of BMI or age with respect to postoperative patient outcomes, which is different from the results of Domb et al.²⁰ Significantly, however, the studies of Domb et al. and Lodhia et al. did not attempt to quantify radiographic parameters and their potential association with clinical outcomes, making the results of our study a meaningful contribution to the existing literature on RHA.

Both groups in our analysis improved, as shown by a mean improvement in the mHHS of 27.6 ± 22.1 and 39.0 ± 13.3 in the failure and success groups, respectively. Similar improvements occurred in the NAHS, with values of 26.3 ± 23.0 and 35.9 ± 15.7 for the failure and success groups, respectively. Additionally, at final follow-up, the average mHHS in our cohort was 76.8, which is similar to the value of 74.61 reported in the results of a meta-analysis on RHA by O'Connor et al.²¹ Of note, our cohort's average NAHS at final follow-up was 80.1, within the range of values reported in the literature on RHA (69.00-83.70).^{22,23} These results suggest that RHA generally has positive implications for patients.

At 2 years' follow-up, 96.2% of patients undergoing RHA achieved the MCID overall whereas only 65.3% of patients achieved the PASS. Of note, there was a statistically significant difference in the rate of patients achieving the PASS between the failure and success groups, with a much higher percentage of patients (83% vs 25%) achieving the PASS at 2 years' follow-up.

Although 6 of our patients were deemed to have a failure because of an mHHS of less than 70, all of these patients reported a greater than 8-point improvement from their preoperative score, showing at least some improvement from RHA. Only 2 patients in our failure cohort (25%) had failure because they underwent

revision procedures. O'Connor et al.²¹ recently reported in a meta-analysis that RHA does indeed result in significant improvements in PROMs but still less than those for primary hip arthroscopy.

Limitations

Despite our findings, this study has several limitations. First, the sample size of our patient population is small, opening this study up to sampling bias and yielding a low fragility index of 0 to 1. Because of the low incidence of RHA at a single institution, we are limited in capturing a large cohort for this evaluation. Second, despite the listed inclusion criteria, the patients included in this study may potentially be a heterogeneous population. The original indication and injury mechanism were not able to be collected for a small percentage of patients, and in this relatively small cohort, the effect is unknown. Additionally, limited intraoperative data analysis was performed and limited femoral version data were available for this cohort, which may have resulted in some confounding. Similarly, although our data reflect differences in radiographic data between groups, the clinical relevance of these data may be somewhat limited by their small overall differences, as well as the statistical difference in baseline PROMs, which has been shown to exert a predictive influence over postoperative outcomes.

Conclusions

Complete resection of cam lesions as determined by changes in the alpha angle, anterior offset, and head-neck ratio when measured on the Dunn 45° view correlates with positive clinical outcomes after RHA.

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