Review Article

Strategies in revision hip arthroscopy

Seper Ekhtiari[1], Ryan P. Coughlin[1], Nicole Simunovic[2], Olufemi R. Ayeni[1]

[1]Division of Orthopaedic Surgery, Department of Surgery, [2]Department of Health Research Methods, Evidence and Impact, McMaster University, Hamilton, ON, Canada

Contributions: (I) Conception and design: RP Coughlin, OR Ayeni; (II) Administrative support: N Simunovic; (III) Provision of study materials or patients: None; (IV) Collection and assembly of date: S Ekhtiari, RP Coughlin; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval: All authors.

Correspondence to: Olufemi R. Ayeni, MD, MSc, FRCSC. McMaster University Medical Centre, 1200 Main St W, Room 4E15, Hamilton, Ontario L8N 3Z5, Canada. Email: ayenif@mcmaster.ca.

Abstract: With the recent increase in the use of hip arthroscopy, revision hip arthroscopy has also become more prevalent. Managing patients with residual and/or recurrent symptoms following hip arthroscopy is diagnostically and technically challenging. It is important to be aware of the most common reasons for failure, such as bony under-resection, labral tear or re-tear, progression of degenerative joint disease, and missed concurrent disorders such as subspine impingement, snapping hip syndrome, and athletic pubalgia. It is also important to rule out extra-articular causes of hip pain, such as referred pain from the spine or trochanteric bursitis. Pre-operative planning is of paramount importance if revision surgery is being considered, and three-dimensional modalities [such as magnetic resonance imaging and computed tomography (CT) with 3D reconstruction] are often required. Appropriate patient selection, honest discussions about potential outcomes, and management of patient expectations are important before proceeding with revision surgery. Intra-operatively, there are specific techniques and assistive technologies (e.g., fluoroscopy, navigation) that can aid in achieving a successful revision. Specific techniques have been developed for use in revision settings, such as labral and/or capsular reconstruction/grafting, remplissage for bony under-resection, and chondral implantation.

Keywords: Hip; arthroscopy; revision; femoroacetabular impingement

Received: 24 November 2017; Accepted: 29 December 2017; Published: 26 January 2018.
doi: 10.21037/aoj.2017.12.01
View this article at: http://dx.doi.org/10.21037/aoj.2017.12.01

Introduction

The utilization of hip arthroscopy to address intra-articular and extra-articular hip pathology has exploded since the early 21st century, with an increase of over 400% in the United States (1), and similar or greater increases in Europe (2) and Asia (3). Naturally, new issues continue to be identified, studied, and addressed. An important aspect of hip arthroscopy is the management of patients with residual or recurrent symptoms following index hip arthroscopy. Data on revision hip arthroscopy is increasingly prevalent in recent literature, including two recent systematic reviews on the topic (4,5). This review discusses the prevalence, etiology, clinical approach, pre-operative planning process, intra-operative strategies, and patient counselling as they relate to revision hip arthroscopy.

Epidemiology & etiology

The rates of revision hip arthroscopy have been reported to be 2–6% (6,7). The reasons for revision hip arthroscopy are multifactorial and continue to be studied, understood, and defined. In broad terms, they can be categorized into intra-articular and extra-articular pathologies. Equally challenging is the difficulty differentiating non-hip related etiologies that can often refer pain or masquerade as hip pathology.

Intra-articular etiologies

Intra-articular etiologies of revision hip arthroscopy include bony under- or over-resection, capsular instability, osteochondral lesions, and osteoarthritis. Bony under-resection has been consistently reported as one of the most common indications for revision hip arthroscopy, responsible for 40–64% of revisions (4,8,9). In fact, Philippon *et al.* (2007) found that 97.3% of patients undergoing revision hip arthroscopy had femoroacetabular impingement (FAI) morphology that was either inadequately addressed or not addressed at all in the index surgery (10). Despite the significant increase in awareness and literature regarding FAI since the publication of that study, a recent cross-sectional study found residual FAI rates of 74–86% in patients requiring revision hip arthroscopy (11).

Instability following hip arthroscopy is a controversial entity. There are undoubtedly some reported cases of catastrophic failure secondary to gross instability after hip arthroscopy; a recent systematic review analyzed nine such cases (12). However, another recent systematic review on the topic found a lack of evidence directly linking closure to the risk of post-operative instability (13). The concept of "micro-instability" is relatively new and poorly defined with no objective criteria (14). A retrospective study of 25 revision hip arthroscopies found 9 patients having repeat surgery for reasons other than residual FAI (alpha angle >55°; CEA >40°). Pre-operative MRA found capsular defects in 7 patients (78%) and all patients had an abnormal capsule at the time of revision surgery with two patients having gross capsular deficiency with exposed muscle visualized from the central compartment. Interestingly, all patients were young, active females which may suggest a particular subgroup that is more prone to developing symptoms of instability (15). Bony over-resection is an even rarer complication of hip arthroscopy, but can result in the loss of the "suction seal" mechanism of the labrum, leading to a presentation similar to that of micro-instability (16). Other etiologies for revision hip arthroscopy include acetabular dysplasia, psoas tendonitis, and osteochondral lesions (11).

Extra-articular etiologies

Data on heterotopic ossification (HO) post-arthroscopy is scarce, but some risk factors have been identified, including male gender, extensive rim trimming, and anchor placement (17,18). Small to medium HO lesions are usually asymptomatic, and HO does not necessarily result in a poorer functional outcome (19). Thus, pain and/or functional limitation should not be automatically attributed to HO unless there are significant radiographic findings (usually Brooker III or IV) along with mechanical limitation on range of motion (20,21). A recent randomized control led study of 106 patients found that rates of HO in patients who received post-operative naproxen was 4% compared to 46% in the placebo group (RR =0.09, CI =0.02 to 0.38, P<0.001). Although enrolment was terminated early due to convincing treatment effect, the study did not report clinical outcomes, and the potential adverse effects of prophylactic non-steroidal anti-inflammatories need to be further evaluated (22).

A number of other causes of hip pain present similarly to, and can occur concurrently with FAI, and should be evaluated with physical examination. Most commonly, these include adductor-related pathology, snapping hip syndrome, "athletic pubalgia", and subspine impingement. Adductor strains and tendonitis can present as hip or groin pain, particularly in athletes (23). Snapping hip syndrome is an audible snapping sound, with or without pain, that is most commonly due to the iliotibial band or gluteus maximus tendon snapping over the greater trochanter during extension (24). Subspine impingement is the result of repeated impingement between the head-neck junction and a hypertrophic anterior inferior iliac spine (AIIS).

Etiologies unrelated to the hip and surrounding structures

A comprehensive review of extra-articular etiologies of persistent and recurrent pain after hip arthroscopy is beyond the scope of this review, but these are important considerations before proceeding with revision hip arthroscopy. Spinal pathology is an important cause of referred hip pain, and should be considered at the very least, and investigated if appropriate (25). What further confuses the issue is the spine-hip syndrome, where often there is co-existing pathology of FAI and degenerative disc disease of the lumbar spine (26). Greater trochanteric bursitis is another cause of hip pain that can be managed non-operatively and should be considered as a potential etiology (27).

Other etiologies

Adherence to post-operative rehabilitation is an important component of positive outcomes following orthopaedic surgery (28). Thus, inadequate rehabilitation can be a potential cause of failure of the index surgery, and should

be discussed with the patient if revision surgery is being considered. Missed concurrent diagnoses (e.g., subspine impingement, adductor pathology, etc.) are also an important potential etiology for revision hip arthroscopy—as outlined above, the hip is a complex joint with many surrounding and nearby structures, and the presence of a given diagnosis does not necessarily exclude the presence of all others.

Clinical presentation

History

A precise history is crucial to correctly identifying the cause of failure. It is important to delineate between residual (i.e., lack of improvement) and recurrent (i.e., period of relief followed by re-occurrence of symptoms) symptoms following index surgery. Several authors have recommended follow-up for at least two years, given that the timeline between index and revision surgery is most commonly between two and three years (6,29,30).

The most common sites for pain in FAI are the groin and the lateral hip (31). Classically, patients may exhibit the "C-sign", whereby the patient points to the anterolateral aspect of the hip with the thumb just above the greater trochanter and the index finger anteriorly (32). This pattern of pain points to an intra-articular etiology, and a further, careful history can help to differentiate between impingement and degenerative causes. As degenerative changes progress, pain becomes more constant, whereas pain related to more focal and acute causes tends to present as sharp, intermittent, related to specific activities and positions, and accompanied by mechanical symptoms such as clicking, locking, or catching (33). Psoas tendonitis is a painful condition that often presents with snapping and/or sharp pain, particularly during deep flexion activities (34). Over 80% of patients with an eventual diagnosis of FAI describe anterior groin pain, even when multiple painful regions are involved (31,35). Thus, in patients presenting with post-operative pain that does not involve the groin at all, a careful diagnostic workup is indicated to rule out extra-articular etiologies.

Physical examination

As in any clinical scenario, a careful physical examination is extremely important as it can help to distinguish between intra-articular and extra-articular pathologies. According to Byrd *et al.*, a full clinical examination has a 98% sensitivity for identifying intra-articular pathology (36). A complete physical examination of the hip should be conducted including gait analysis, stance, neurovascular status, palpation, range of motion, and special tests. Viswanath *et al.* provide a detailed, evidence-based approach to physical examination of the hip, the details of which are beyond the scope of this review (37). Specific examination manoeuvres relevant to revision hip arthroscopy are highlighted in this section.

Muscular weakness is common in the acute post-operative period, but patients should expect to regain or exceed their pre-operative strength by six months post-operatively (38). The exception to this is hip flexor strength, which may remain weaker even 2.5 years post-arthroscopy (38). In addition, the index arthroscopic surgery may have included iliopsoas lengthening or tenotomy. Weakness and/or pain on resisted hip flexion compared to the contralateral side suggest pathology involving the iliopsoas muscle, though the diagnostic utility is unclear, with specificity reported between 0.38 and 1.0, and sensitivity of 0.06–0.75 (39). Positive Trendelenburg sign suggests abductor muscle weakness (40). The anterior and posterior apprehension tests, which are conceptually similar to apprehension testing for the shoulder, can be used to assess for micro-instability. The anterior apprehension test is performed with the patient supine, with the buttocks at the edge of the table. The affected extremity is taken into extension and external rotation. The posterior apprehension test is performed with the affected hip flexed to 90°, adducted, and internally rotated. A posteriorly directed force is then applied. In both tests, a positive test reproduces pain and/or feelings of instability (14).

Non-FAI related hip pathologies that also present with hip and/or groin symptoms should also be evaluated. Adductor tendonitis and strains can present with tenderness over the adductor tendon and/or muscle belly, and pain on passive abduction and resisted adduction (23). Snapping hip can be readily observed during physical examination. For confirmation, the patient can be placed in the lateral decubitus position on the unaffected hip. The affected hip is then taken into extension while pressure is placed on the greater trochanter to prevent snapping of the tendon(s) (24). Tenderness to palpation over the AIIS is suggestive of subspine impingement (41).

Multiple special tests have demonstrated high sensitivity in identifying intra-articular hip pathology, including labral tears and FAI. These include the anterior impingement

test (Sensitivity =0.59–1.0), flexion-abduction-external rotation (FABER) test (0.41–0.97), the Fitzgerald test (0.96), the hip quadrant test (0.88–1.0), the Thomas test (0.89), and the internal rotation-flexion-axial compression test (0.75–0.89) (39). There is no strong evidence to support the ability of these tests to distinguish between the various causes of intra-articular hip pathology, but one or more positive tests likely warrant further investigation.

Investigations

Laboratory tests

Superficial and deep infections following hip arthroscopy are quite rare, with superficial wound infections reported in less than 3% of patients (42-45), and only two reported cases of deep infection identified following hip arthroscopy (46,47). Despite their rarity, clinical suspicion should be maintained at a high level as the consequences of septic arthritis in a young patient can be devastating. Thus, if clinically indicated, a complete blood cell count, C-reactive protein, erythrocyte sedimentation rate, and image-guided joint aspiration can help to guide diagnosis (48). If necessary, hip arthroscopy is a safe and effective management strategy for septic arthritis (49), though there is no specific data on its use in a revision context.

Diagnostic imaging

Plain radiographs can reveal bony causes for failure of the index surgery, and should include AP pelvis, lateral of the affected hip, and a Dunn lateral in 45° of flexion which can reveal residual cam deformity (most commonly at the 1:15 position) (50). Given that bony under-resection is one of the most common reasons for revision hip arthroscopy (10), careful examination of pre- and post-operative radiographs is crucial. Bony over-resection, though much more rare, can also be identified radiographically.

Fluoroscopic or ultrasound-guided intra-articular injections (e.g., local anesthetic, or less commonly corticosteroid or hyaluronic acid) have excellent diagnostic utility in distinguishing intra-articular pathology from extra-articular and non-hip related pathology (sensitivity 0.91–1.0, specificity 0.81–1.0) (51-53). In addition, intra-articular injections represent a therapeutic option that may temporize or altogether avoid the need for revision surgery, though less than half of patients with FAI benefit from pain relief following an intra-articular injection of the hip (54).

Ultrasonographic examination may be indicated if infection is suspected to assess for a joint effusion, and may or may not be accompanied by joint aspiration. Ultrasound is also useful in assessing dynamic hip pathologies, such as subspine impingement and snapping hip syndrome (24,41). Finally, ultrasound can be used to help diagnose pathologies related to the many tendons and bursae in and around the hip joint (55).

Advanced imaging should be strongly considered in the revision arthroscopy setting. One or both of computed tomography (CT) or magnetic resonance imaging (MRI) may be necessary to identify all causes of failure and to assist in pre-operative planning. Three-dimensional reconstruction with CT or MRI can also help to more adequately and accurately target such etiologies as subtle residual bony lesions, focal acetabular over-coverage (56), and HO (50). MR Arthrography has superior diagnostic utilities compared to plain MRI for diagnosing labral tears (sensitivity 0.87, specificity 0.64) (57). Recent advances in technology have made 3D printing an important and viable option for pre-operative planning, helping to reduce operative time and increase accuracy (58). Though no literature was identified on the application of 3D printing in the context of hip arthroscopy, it is an option that may be considered in highly complex revision cases if the resources are available (e.g., dysplasia or other anatomic deformities).

Operative management

Pre-operative planning

As with any operation, careful pre-operative planning is a major determinant of post-operative outcome. Particularly in a revision setting, where the operation may be more technically challenging and the peri-operative risks greater, a detailed pre-operative plan can be the difference between success and failure. A review of history, physical examination and imaging is important in identifying the diagnosis for failure and the goals of the revision operation. A careful study of the index operative report is essential, and can help identify reasons for failure (e.g., extensive cartilage loss), procedures performed (e.g., psoas tenotomy, capsular repair *vs.* no repair), and technical challenges (e.g., distorted anatomy, tight musculature, etc.).

Intra-operative strategies

Bony under-resection, as one of the most common causes

of revision hip arthroscopy, is important to evaluate and address. Once again, the importance of pre-operative planning cannot be over-stated. Intra-operative fluoroscopy can only provide two-dimensional cuts of the joint anatomy, and residual lesions are best addressed if their location and extent have been identified with pre-operative 3D modalities (50). Thus, intra-operative fluoroscopic imaging should be used to assist the execution of the pre-operative plan, and not as a real-time diagnostic tool. Navigated cam resection is an exciting new option in which a software is used pre-operatively to simulate hip movements and identify the extent of resection required. The resection is then undertaken with active feedback from the navigation system. In one study, navigated resection lead to improved accuracy, but greater radiation exposure and longer operative time (59). Residual cam deformity most commonly occurs at the superior head-neck junction, specifically at the 1:15 position. This is likely due to the technical difficulties associated with global arthroscopic assessment in this area, which often has to be viewed through accessory portals in a regional fashion (50). Again, pre-operative planning and the use of appropriate assistive technology should be considered, particularly in a revision setting (e.g., 3D fluoroscopy, navigation software, etc.). Resection of HO lesions can be performed arthroscopy, though at least six months to one year should be allowed for full bony maturation to reduce the likelihood of recurrence (60).

The data on hip arthroscopy for chondral lesions is limited, but early data shows some promising results in the short term. A recent systematic review looking at twelve different studies on the arthroscopic management of chondral lesions found significant improvements across all cohorts (61). A number of different techniques can be used to address chondral lesions. Philippon *et al.* first reported on microfracture for chondral lesions in nine patients, with an average fill percentage of 91% at second-look arthroscopy (62). More recent data has corroborated this finding with positive clinical outcomes in short-term follow-up (61). Recent advances in technology have made possible exciting new techniques for the treatment of chondral lesions. Specifically, this includes whole-tissue and cell-based (with or without the use of a scaffold) transplantation techniques. In whole-tissue osteochondral transfer, autologous or allogenic osteochondral plugs are harvested from non-weight-bearing surfaces of the hip or knee joint. The recipient site in the hip joint is then drilled to the desired depth, the graft inserted, and tamped into position to achieve a congruent articular surface (63). In contrast, cell-based chondrocyte implantation requires harvesting of chondrocytes (either autologous or allogenic), and the isolation and expansion of the cells in a laboratory setting. A matrix may or may not be used to promote cell proliferation. Once the graft has matured, the recipient site is prepared for graft implantation, and the graft then implanted. Traction is released and the hip is taken through 4–6 arcs of motion, following which the graft position is confirmed. Of note, if autologous chondrocyte implantation is used, the patient must undergo two surgeries—one for harvest and another for implantation (64). Finally, the use of a synthetic osteochondral plug has been described by Field *et al.*, in which a synthetic plug is inserted into the site of the lesion. Overall, a recent systematic review found promising results with short-term follow-up for all of the above techniques (65).

Symptomatic labral re-tear and/or insufficiency may need to be addressed in a revision setting. The options for addressing labral pathology, depending on the extent of the defect, include debridement, repair, and reconstruction. Debridement may be used for symptomatic focal tears or cysts (66). The affected labrum is debrided to a stable bleeding rim of bone, ensuring that the debridement is kept to the minimum amount required to achieve a stable flap (67). It is unclear whether simple debridement has any clinical benefit, particularly in older patients (68-71), and whether or not it results in subsequent labral regeneration (72,73). In a revision setting, if labral debridement at the index operation has failed to result in labral regrowth, repeat debridement may be of limited utility.

Labral repair is recommended for detached or torn (but not degenerative) labrum where there is sufficient high-quality tissue amenable to repair. The labrum may need to be detached carefully and held with a stay suture to allow access to the underlying acetabular rim. Some rim trimming is necessary to provide a stable, bleeding bone bed for repair (74). In a revision context, particularly if previous labral/acetabular work has been performed, care should be taken to avoid over-resection. Awareness of the pre-operative lateral centre-edge angle (LCEA) can help guide the appropriate amount of resection (75). Finally, the labrum is re-attached to the rim using one of a variety of previously described techniques, including with sutures and anchors (74,76-78).

Labral reconstruction may be indicated when a labral tear is irreparable, either due to insufficient volume or quality of tissue. In the revision setting in particular, early

evidence has shown a lower rate of failure as compared to labral repair, and may be necessary due to previously damaged and/or resected labrum (75,79). A number of different techniques have been described for arthroscopic labral reconstruction, most commonly with iliotibial or semitendinosus auto- or allografts (79). Three arthroscopic portals are required to maintain graft tension during the procedure (79). Once again, femoral and acetabular osteochondroplasty is performed as necessary to address any FAI lesions and to provide a suitable bone bed for graft fixation. The labral defect is then measured, and a graft larger than the measured size is prepared. The graft is thawed if necessary, soaked in a saline and antibiotic solution, and rolled into a ~5 mm diameter tubular graft. The graft is then introduced into the joint and tied with circumferential sutures or anchors to the bone bed. Excess graft is removed and examined dynamically and without traction for stability, to ensure there is no impingement, and to ensure restoration of the suction seal (79).

Capsular instability remains a controversial topic post-hip arthroscopy, and it is unclear if capsular repair reduces its occurrence (13). Nonetheless, both gross and micro-instability have been reported post-hip arthroscopy, and should be taken into consideration in a revision setting (12,14). In patients who have sufficient remaining capsular tissue, a direct repair, with or without plication can be performed to close and tighten the capsule following the revision operation. This procedure involves excision of a small section of capsule (an oval-shaped area 8–10×12–15 mm), the interval between which is then closed. In rare cases where there is insufficient tissue for capsular closure or repair, an allograft can be considered (60). Capsular repair and/or plication should certainly be considered in patients with known risk factors, such as female sex, global ligamentous laxity, and connective tissue disorders such as Ehlers-Danlos syndrome (13).

Capsular reconstruction may be necessary in patients with deficient capsular tissue at revision. This can be performed using the native capsular tissue in some cases by reattaching the capsule and the iliofemoral ligament to their footprint, and a capsular closure performed distal to proximal, with suture anchors at the proximal end. Sutures are used to close the capsule in a side-to-side convergence technique (80). Grafting options are available in cases of severe capsular deficiency, and a number of different techniques have been described including iliotibial band autograft (81), Achilles' tendon allograft (82), and dermal allografts (83,84).

Bony over-resection, though rare, can also be addressed arthroscopically. Frank *et al.* have described a remplissage technique that can be used to correct excessive resection of a cam lesion (16). In this procedure, an iliotibial band allograft is prepared based on the shape and size of the defect. The graft is loaded onto a suture anchor and introduced into the joint. It is then positioned at the site of the defect, and tied down into the bone. Further anchors can be placed along the length of the defect. This procedure can help to restore the suction seal and address iatrogenic instability (16). As this is a recently described procedure, no clinical data is available on outcomes, including post-operative range of motion.

The above procedures can also be performed with open surgical approaches, and this may be considered in cases where arthroscopy may be deemed too difficult or unlikely to succeed, for example in the context of gross anatomic deformities or a multiply revised hip. The higher peri-operative risk and lengthier recovery with comparable open procedures versus arthroscopy should be considered when deciding on the surgical approach (85).

Patient selection/expectation management

Patients should be selected carefully for revision hip arthroscopy. While a majority of patients do improve following revision hip arthroscopy, 15–35% of patients are not satisfied (4,8,86). Total hip arthroplasty (8–14%) and re-revision hip arthroscopy (7–8%) are required in some patients following revision hip arthroscopy within 1–2 years (4,86). Previous literature has identified older age, cartilage injuries, workers' compensation, and female sex as predictors of relatively poorer outcome after primary hip arthroscopy, and the same can be expected to apply to revision hip arthroscopy (87,88).

Finally, management of patient expectations is important, particularly in a revision context. A matched-cohort study comparing 246 patients requiring revision hip arthroscopy to 492 primary surgeries showed the Hip Outcome Score-Activities of Daily Living (HOS-ADL) was lower in the revision cohort preoperatively (65 *vs.* 70) and postoperatively (79 *vs.* 87) (P=0.001). A similar finding was seen with regards to the HOS-sports, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Short-Form 12 (SF12) physical component scores (89). Thus, while revision hip surgery may provide meaningful benefits to patients, it clearly emphasizes the importance of managing expectations to help improve patient satisfaction

in the post-operative period. Hip and knee arthroplasty literature has demonstrated that pre-operative patient expectations impact post-operative patient-reported outcomes (90). Counselling patients based on the available evidence is a key component of obtaining informed consent. As well, a frank discussion regarding the possible reasons for failure of the primary surgery can help to guide diagnosis and decision-making in the revision context.

Conclusions

With the significant increase in the utilization of hip arthroscopy, revision hip arthroscopy is also becoming more common. Up to 6% of patients undergoing primary hip arthroscopy require revision arthroscopy. Some of the most common causes for revision surgery include inadequately addressed FAI, labral degeneration or re-tear, and degenerative joint disease. A careful history and physical is important in differentiating between intra-articular, extra-articular, and non-hip related sources of persistent or recurrent pain following hip arthroscopy. Basic and advanced imaging, including the use of three-dimensional modalities, is important in guiding diagnosis and pre-operative planning. Intra-operatively, bony lesions should be carefully and sufficiently addressed, particularly those in locations that are difficult to visualize. Labral lesions often require repair or reconstruction due to a lack of high-quality tissue. Overall, revision hip arthroscopy is less successful than index surgery and patients should be carefully selected and their expectations managed clearly.

Acknowledgments

The authors acknowledge Mr. Matthew Skelly and Mr. Andrew Duong for their help in the preparation and submission of this manuscript.
Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *Annals of Joint* for the series "Future Perspectives in Hip Preservation and Arthroscopy". The article has undergone external peer review.

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/aoj.2017.12.01). The series "Future Perspectives in Hip Preservation and Arthroscopy" was commissioned by the editorial office without any funding or sponsorship. RPC served as the unpaid Guest Editor of the series. ORA served as the unpaid Guest Editor of the series and serves as an unpaid editorial board member of *Annals of Joint* from Aug 2017 to Jul 2019. ORA reports that he is Speakers bureau for Conmed. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Maradit Kremers H, Schilz SR, Van Houten HK, et al. Trends in utilization and outcomes of hip arthroscopy in the United States between 2005 and 2013. J Arthroplasty 2017;32:750-5.
2. Palmer AJ, Malak TT, Broomfield J, et al. Past and projected temporal trends in arthroscopic hip surgery in England between 2002 and 2013. BMJ open Sport Exerc Med 2016;2:e000082.
3. Lee YK, Ha YC, Yoon BH, et al. National trends of hip arthroscopy in Korea. J Korean Med Sci 2014;29:277-80.
4. Sardana V, Philippon MJ, de Sa D, et al. Revision Hip Arthroscopy Indications and Outcomes: A Systematic Review. Arthroscopy 2015;31:2047-55.
5. Cvetanovich GL, Harris JD, Erickson BJ, et al. Revision hip arthroscopy: a systematic review of diagnoses, operative findings, and outcomes. Arthroscopy 2015;31:1382-90.
6. Tissot C, Merlini L, Mercier M, et al. Reasons for and functional results of repeated hip arthroscopy: A continuous prospective study of 17 revisions out of 295 primary hip arthroscopies at mean 28 months' follow-up. Orthop Traumatol Surg Res 2017;103:645-9.
7. Harris JD, McCormick FM, Abrams GD, et al.

Complications and reoperations during and after hip arthroscopy: A systematic review of 92 studies and more than 6,000 patients. Arthroscopy 2013;29:589-95.
8. Gwathmey FW, Byrd JW, Jones K. Revision hip arthroscopy: findings and outcomes. Arthroscopy 2014;30:e23.
9. Haefeli PC, Albers CE, Steppacher SD, et al. What are the risk factors for revision surgery after hip arthroscopy for femoroacetabular impingement at 7-year followup? Clin Orthop Relat Res 2017;475:1169-77.
10. Philippon MJ, Schenker ML, Briggs KK, et al. Revision hip arthroscopy. Am J Sports Med 2007;35:1918-21.
11. Ricciardi BF, Fields K, Kelly BT, et al. Causes and risk factors for revision hip preservation surgery. Am J Sports Med 2014;42:2627-33.
12. Yeung M, Memon M, Simunovic N, et al. Gross instability after hip arthroscopy: an analysis of case reports evaluating surgical and patient factors. Arthroscopy 2016;32:1196-204.e1.
13. Ekhtiari S, de Sa D, Haldane CE, et al. Hip arthroscopic capsulotomy techniques and capsular management strategies: a systematic review. Knee Surg Sports Traumatol Arthrosc 2017;25:9-23.
14. Kalisvaart MM, Safran MR. Microinstability of the hip—it does exist: etiology, diagnosis and treatment. J Hip Preserv Surg 2015;2:123-35.
15. McCormick F, Slikker W, Harris JD, et al. Evidence of capsular defect following hip arthroscopy. Knee Surg Sports Traumatol Arthrosc 2014;22:902-5.
16. Frank JM, Chahla J, Mitchell JJ, et al. Remplissage of the femoral head-neck junction in revision hip arthroscopy: a technique to correct excessive cam resection. Arthrosc Tech 2016;5:e1209-13.
17. Randelli F, Pierannunzii L, Banci L, et al. Heterotopic ossifications after arthroscopic management of femoroacetabular impingement: the role of NSAID prophylaxis. J Orthop Traumatol 2010;11:245-50.
18. Beckmann JT, Wylie JD, Kapron AL, et al. The effect of NSAID prophylaxis and operative variables on heterotopic ossification after hip arthroscopy. Am J Sports Med 2014;42:1359-64.
19. Rath E, Sherman H, Sampson TG, et al. The incidence of heterotopic ossification in hip arthroscopy. Arthroscopy 2013;29:427-33.
20. Larson CM, Giveans MR. Arthroscopic management of femoroacetabular impingement: early outcomes measures. Arthroscopy 2008;24:540-6.
21. Amar E, Sharfman ZT, Rath E. Heterotopic ossification after hip arthroscopy. J Hip Preserv Surg 2015;2:355-63.
22. Beckmann JT, Wylie JD, Potter MQ, et al. Effect of naproxen prophylaxis on heterotopic ossification following hip arthroscopy: a double-blind randomized placebo-controlled trial. J Bone Joint Surg Am 2015;97:2032-7.
23. Valent A, Frizziero A, Bressan S, et al. Insertional tendinopathy of the adductors and rectus abdominis in athletes: a review. Muscles Ligaments Tendons J 2012;2:142-8.
24. Lee KS, Rosas HG, Phancao JP. Snapping hip: imaging and treatment. Semin Musculoskelet Radiol 2013;17:286-94.
25. Prather H, Cheng A, Steger-May K, et al. Hip and lumbar spine physical examination findings in people presenting with low back pain, with or without lower extremity pain. J Orthop Sports Phys Ther 2017;47:163-72.
26. Gebhart JJ, Weinberg DS, Conry KT, et al. Hip-spine syndrome: is there an association between markers for cam deformity and osteoarthritis of the lumbar spine? Arthroscopy 2016;32:2243-8.
27. Williams BS, Cohen SP. Greater trochanteric pain syndrome: a review of anatomy, diagnosis and treatment. Anesth Analg 2009;108:1662-70.
28. Mendonza M, Patel H, Bassett S. Influences of psychological factors and rehabilitation adherence on the outcome post anterior cruciate ligament injury/surgical reconstruction. New Zealand J Physiother 2007;35:62-71.
29. Aprato A, Jayasekera N, Villar RN. Revision hip arthroscopic surgery: outcome at three years. Knee Surg Sports Traumatol Arthrosc 2014;22:932-7.
30. Domb BG, Stake CE, Lindner D, et al. Revision hip preservation surgery with hip arthroscopy: clinical outcomes. Arthroscopy 2014;30:581-7.
31. Clohisy JC, Knaus ER, Hunt DM, et al. Clinical presentation of patients with symptomatic anterior hip impingement. Clin Orthop Relat Res 2009;467:638-44.
32. Dooley PJ. Femoroacetabular impingement syndrome. Can Fam Physician 2008;54:42-7.
33. Byrd JWT. Femoroacetabular impingement in athletes: current concepts. Am J Sports Med 2014;42:737-51.
34. Anderson CN. Iliopsoas: pathology, diagnosis, and treatment. Clin Sports Med 2016;35:419-33.
35. Philippon MJ, Maxwell RB, Johnston TL, et al. Clinical presentation of femoroacetabular impingement. Knee Surg Sports Traumatol Arthrosc 2007;15:1041-7.
36. Byrd JWT, Jones KS. Diagnostic accuracy of clinical

assessment, magnetic resonance imaging, magnetic resonance arthrography, and intra-articular injection in hip arthroscopy patients. Am J Sports Med 2004;32:1668-74.
37. Viswanath A, Khanduja V. Clinical diagnosis of FAI: an evidence-based approach to history and physical examination of the hip. In: Ayeni O, Karlsson J, Philippon MJ, Safran MR, editors. Diagnosis and Management of Femoroacetabular Impingement: An Evidence-Based Approach. New York: Springer, 2017:27-38.
38. Casartelli NC, Maffiuletti NA, Item-Glatthorn JF, et al. Hip muscle strength recovery after hip arthroscopy in a series of patients with symptomatic femoroacetabular impingement. HIP Int 2014;24:387-93.
39. Tijssen M, Van Cingel R, Willemsen L, et al. Diagnostics of femoroacetabular impingement and labral pathology of the hip: A systematic review of the accuracy and validity of physical tests. Arthroscopy 2012;28:860-71.
40. Ebert JR, Retheesh T, Mutreja R, et al. The clinical, functional and biomechanical presentation of patients with symptomatic hip abductor tendon tears. Int J Sports Phys Ther 2016;11:725-37.
41. Blankenbaker DG, Tuite MJ. Non-femoroacetabular impingement. Semin Musculoskelet Radiol 2013;17:279-85.
42. El Bitar YF, Stake CE, Dunne KF, et al. Arthroscopic iliopsoas fractional lengthening for internal snapping of the hip: clinical outcomes with a minimum 2-year follow-up. Am J Sports Med 2014;42:1696-703.
43. Domb BG, Linder D, Finley Z, et al. Outcomes of hip arthroscopy in patients aged 50 years or older compared with a matched-pair control of patients aged 30 years or younger. Arthroscopy 2015;31:231-8.
44. Larson CM, Stone RM, Grossi EF, et al. Ehlers-Danlos syndrome: arthroscopic management for extreme soft-tissue hip instability. Arthroscopy 2015;31:2287-94.
45. Pailhé R, Chiron P, Reina N, et al. Pudendal nerve neuralgia after hip arthroscopy: retrospective study and literature review. Orthop Traumatol Surg Res 2013;99:785-90.
46. Clarke MT, Arora A, Villar RN. Hip arthroscopy: complications in 1054 cases. Clin Orthop Relat Res 2003;(406):84-8.
47. Chan K, Farrokhyar F, Burrow S, et al. Complications following hip arthroscopy: a retrospective review of the McMaster experience (2009-2012). Can J Surg 2013;56:422-6.
48. Mathews CJ, Kingsley G, Field M, et al. Management of septic arthritis: a systematic review. Postgrad Med J 2008;84:265-70.
49. Heaven S, de Sa D, Simunovic N, et al. Hip arthroscopy in the setting of hip arthroplasty. Knee Surg Sports Traumatol Arthrosc 2016;24:287-94.
50. Ross JR, Larson CM, Adeoye O, et al. Residual deformity is the most common reason for revision hip arthroscopy: a three-dimensional CT study. Clin Orthop Relat Res 2015;473:1388-95.
51. Chandrasekaran S, Lodhia P, Suarez-Ahedo C, et al. Symposium: evidence for the use of intra-articular cortisone or hyaluronic acid injection in the hip. J Hip Preserv Surg 2015;3:5-15.
52. Crawford RW, Gie GA, Ling RSM, et al. Diagnostic value of intra-articular anaesthetic in primary osteoarthritis of the hip. J Bone Joint Surg Br 1998;80:279-81.
53. Deshmukh AJ, Thakur RR, Goyal A, et al. Accuracy of diagnostic injection in differentiating source of atypical hip pain. J Arthroplasty 2010;25:129-33.
54. Khan W, Khan M, Alradwan H, et al. Utility of intra-articular hip injections for femoroacetabular impingement. Orthop J Sports Med 2015;3:2325967115601030.
55. Nestorova R, Vlad V, Petranova T, et al. Ultrasonography of the hip. Med Ultrason 2012;14:217-24.
56. Murphy RJ, Subhawong TK, Chhabra A, et al. A quantitative method to assess focal acetabular overcoverage resulting from pincer deformity using CT data. Clin Orthop Relat Res 2011;469:2846-54.
57. Smith TO, Hilton G, Toms AP, et al. The diagnostic accuracy of acetabular labral tears using magnetic resonance imaging and magnetic resonance arthrography: a meta-analysis. Eur Radiol 2011;21:863-74.
58. Hoang D, Perrault D, Stevanovic M, et al. Surgical applications of three-dimensional printing: a review of the current literature & how to get started. Ann Transl Med 2016;4:456.
59. Van Houcke J, Khanduja V, Nakano N, et al. Accuracy of navigated cam resection in femoroacetabular impingement: a randomised controlled trial. Int J Med Robot 2017;13.
60. Beckmann JT, Safran MR. Revision FAI surgery. In: Diagnosis and Management of Femoroacetabular Impingement: An Evidence-Based Approach. New York: Springer, 2017:241-53.
61. Marquez-Lara A, Mannava S, Howse EA, et al. Arthroscopic management of hip chondral defects: a systematic review of the literature. Arthroscopy 2016;32:1435-43.

62. Philippon MJ, Schenker ML, Briggs KK, et al. Can microfracture produce repair tissue in acetabular chondral defects? Arthroscopy 2008;24:46-50.
63. Kubo T, Utsunomiya H, Watanuki M, et al. Hip arthroscopic osteochondral autologous transplantation for treating osteochondritis dissecans of the femoral head. Arthrosc Tech 2015;4:e675-80.
64. Jannelli E, Fontana A. Arthroscopic treatment of chondral defects in the hip: AMIC, MACI, microfragmented adipose tissue transplantation (MATT) and other options. SICOT-J 2017;3:43.
65. Horner NS, Ekhtiari S, Simunovic N, et al. Early evidence reports positive outcomes after osteochondral grafts and chondrocyte transplantation in the hip: a systematic review. J ISAKOS 2016;1:240-9.
66. Queiroz MC. Labral debridement, labral reconstruction or labral repair in revision hip arthroscopy. In: ISHA Annual Scientific Meeting. San Francisco, 2016.
67. Wilkin G, March G, Beaulé PE. Arthroscopic acetabular labral debridement in patients forty-five years of age or older has minimal benefit for pain and function. J Bone Joint Surg Am 2014;96:113-8.
68. Forster-Horvath C, von Rotz N, Giordano BD, et al. Acetabular labral debridement/segmental resection versus reconstruction in the comprehensive treatment of symptomatic femoroacetabular impingement: a systematic review. Arthroscopy 2016;32:2401-15.
69. Haddad B, Konan S, Haddad FS. Debridement versus re-attachment of acetabular labral tears: A review of the literature and quantitative analysis. Bone Joint J 2014;96-B:24-30.
70. Baldwin KD, Harrison RA, Namdari S, et al. Outcomes of hip arthroscopy for treatment of femoroacetabular impingement: a systematic review. Current Orthopaedic Practice 2009;20:669-73.
71. Krych AJ, Kuzma SA, Kovachevich R, et al. Modest mid-term outcomes after isolated arthroscopic debridement of acetabular labral tears. Knee Surg Sports Traumatol Arthrosc 2014;22:763-7.
72. Miozzari HH, Celia M, Clark JM, et al. No regeneration of the human acetabular labrum after excision to bone. Clin Orthop Relat Res 2015;473:1349-57.
73. Abrams GD, Safran MR, Sadri H. Spontaneous hip labrum regrowth after initial surgical Débridement hip. Clin Orthop Relat Res 2013;471:2504-8.
74. Philippon MJ, Faucet SC, Briggs KK. Arthroscopic hip labral repair. Arthrosc Tech 2013;2:e73-6.
75. White BJ, Patterson J, Herzog MM. Revision arthroscopic acetabular labral treatment: repair or reconstruct? Arthroscopy 2016;32:2513-20.
76. Stubbs AJ, Andersen JS, Mannava S, et al. Arthroscopic hip labral repair: the Iberian suture technique. Arthrosc Tech 2014;3:e351-4.
77. Ye K, Singh PJ. Arthroscopic labral repair of the hip, using a through-labral double-stranded single-pass suture technique. Arthrosc Tech 2014;3:e615-9.
78. Slikker W, Van Thiel GS, Chahal J, et al. The use of double-loaded suture anchors for labral repair and capsular repair during hip arthroscopy. Arthrosc Tech 2012;1:e213-7.
79. White BJ, Herzog MM. Labral reconstruction: when to perform and how. Front Surg 2015;2:27.
80. Cuéllar R, Cuéllar A, Sánchez A, et al. Anatomic hip capsular reconstruction with separate suture anchors. Arthrosc Tech 2016;5:e657-66.
81. Dierckman BD, Guanche CA. Anterior hip capsuloligamentous reconstruction for recurrent instability after hip arthroscopy. Am J Orthop (Belle Mead NJ) 2014;43:E319-23.
82. Mei-Dan O, Garabekyan T, McConkey M, et al. Arthroscopic anterior capsular reconstruction of the hip for recurrent instability. Arthrosc Tech 2015;4:e711-5.
83. Chahla J, Dean CS, Soares E, et al. Hip capsular reconstruction using dermal allograft. Arthrosc Tech 2016;5:e365-9.
84. Perets I, Hartigan DE, Walsh JP, et al. Arthroscopic capsular reconstruction of the hip with acellular dermal extracellular matrix: surgical technique. Arthrosc Tech 2016;5:e1001-5.
85. Zhang D, Chen L, Wang G. Hip arthroscopy versus open surgical dislocation for femoroacetabular impingement: a systematic review and meta-analysis. Medicine (Baltimore) 2016;95:e5122.
86. Gupta A, Redmond JM, Stake CE, et al. Outcomes of revision hip arthroscopy: 2-Year Clinical Follow-up. Arthroscopy 2016;32:788-97.
87. Horner NS, Ekhtiari S, Simunovic N, et al. Hip arthroscopy in patients age 40 or older: a systematic review. Arthroscopy 2017;33:464-75.e3.
88. Lund B, Mygind-Klavsen B, Grønbech Nielsen T, et al. Danish hip arthroscopy registry (dhar): the outcome of patients with femoroacetabular impingement (FAI). J Hip Preserv Surg 2017;4:170-7.
89. Newman JT, Briggs KK, McNamara SC, et al. Revision

hip arthroscopy: a matched-cohort study comparing revision to primary arthroscopy patients. Am J Sports Med 2016;44:2499-504.

90. Neuprez A, Delcour JP, Fatemi F, et al. Patients' expectations impact their satisfaction following total hip or knee arthroplasty. PLoS One 2016;11:e0167911.

doi: 10.21037/aoj.2017.12.01
Cite this article as: Ekhtiari S, Coughlin RP, Simunovic N, Ayeni OR. Strategies in revision hip arthroscopy. Ann Joint 2018;3:7.