Complications with Hip Arthroscopy and Open Hip Surgery

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Contents

Abstract

Recognition of femoroacetabular impingement as a potential precursor to hip osteoarthritis has led to the development of both open and arthroscopic hip preservation surgery. Successful short- and midterm clinical outcomes have been reported following hip preservation surgery. Improvements in technique and instrumentation have led to a dramatic increase in the number of surgeons performing hip arthroscopy and the number of cases performed internationally. However, there is a significant learning curve associated with hip arthroscopy. Although the rate of minor complications is low (7.5 %), it is largely related to the learning curve. The two most common minor complications are iatrogenic chondrolabral injury and temporary neuropraxia. Open surgical hip dislocation permits a 360° view of the femoral head and acetabulum but requires a larger incision, greater soft tissue dissection, and a trochanteric osteotomy. Although the rate of minor complications is reportedly higher following open surgical hip dislocation due to the occasional development of painful hardware requiring removal, the rate of major complications is less than 1 % in both open and arthroscopic hip preservation surgery. Thus, both open and arthroscopic hip preservation surgeries appear to be safe. Lack of clarity in reporting complications within orthopedic surgery has spurred academic hip surgeons to adapt and test a general surgery-validated complication reporting system for use in hip preservation.

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Introduction

Hip preservation surgery encompasses both arthroscopic and open non-arthroplasty approaches. The role of hip arthroscopy has been rapidly evolving for the treatment of a variety of hip disorders including femoroacetabular impingement (FAI) and labral tears [1–3]. Recognition of the steep learning curve associated with hip arthroscopy and new techniques for managing hip disorders has led to better recognition and increased efforts to avoid complications [4–6]. The prevalence of complications associated with arthroscopy has been reported to be 8.1 % (7.5 % minor; 0.58 % major) in a comprehensive systematic review of over 6,000 subjects [7]. Iatrogenic chondrolabral injury and temporary neuropraxia were the two most common minor complications. The reoperation rate was 6.3 %, and the most common reason for reoperation was conversion to total hip arthroplasty. Minor complications and reoperation rates were directly related to the learning curve of hip arthroscopy. However, there have been no published prospective studies that specifically and comprehensively assess complications at predetermined time points. This has prompted a prospective analysis performed by surgeons at different institutions in the ANCHOR study group (Academic Network of Conservational Hip Outcomes Research) that should optimally determine the true rate of complications after hip arthroscopy using a validated and reliable classification system [8].

Despite the dramatic increase in the number of arthroscopic hip procedures performed, there are clearly indications for open hip preservation techniques (e.g., surgical hip dislocation and mini-open anterior approach) that are largely based on the complexity of hip pathomorphology and ability to access and correct these regions arthroscopically. Although open approaches are more invasive than arthroscopy and have their own inherent unique complications, an extensive degree of soft tissue trauma can result from arthroscopic procedures with improper technique. The incidence of complications and reoperations has recently been reported comparing arthroscopic and open approaches [9]. The rate of reoperation following surgical dislocation was 41 %, which was significantly greater than that of arthroscopic-assisted mini-open (19 %), mini-open (10 %), and arthroscopy (3 %). Ninety-five percent of reoperations following surgical dislocation were for painful hardware removal. Although there were significantly more temporary nerve palsies following arthroscopy (1.7 %) versus surgical dislocation (0.17 %), they are still uncommon. Other complications after arthroscopic and/or open hip preservation surgery include heterotopic ossification, avascular necrosis, fluid extravasation, infection, instability, femoral neck fracture, venous thromboembolism, among others.

Surgical Anatomy

The hip joint is deep, with a highly congruent articulation between the femoral head and acetabulum and a thick capsuloligamentous and muscular covering. Thus, access via arthroscopy is technically more demanding compared to knee or shoulder arthroscopy. Access via open surgical approaches requires larger degrees of soft tissue dissection and mobilization with the need for trochanteric osteotomy for surgical hip dislocation. Any surgical approach to the hip mandates that the surgeon be comfortable with the pathoanatomy being treated to avoid complications and persistent disability from residual deformity. Protection of the medial femoral circumflex vessels and terminal vessels reduces the risk of avascular necrosis. The risk of neural injury can be minimized with safe arthroscopic portal placement, reduced magnitude and duration of traction during arthroscopy, and meticulous layer-by-layer dissection with open incisions. Furthermore, a degree of capsulotomy is required to access FAI deformities, and failure to close capsulotomies in certain situations may result in postoperative instability [10, 11].

Strict adherence to appropriate surgical indications may improve postoperative outcomes. Given that there is a high prevalence of abnormal radiographic findings suggestive of FAI in asymptomatic patients, understanding the various pain

Table 1 Layer concept of hip anatomy and pathoanatomy [12]

Layer	Anatomy	Pathoanatomy
I Osteochondral	Femoral head	Cam impingement
	Acetabulum	Pincer impingement
		Sub-spine (AIIS) impingement
II Inert	Joint capsule	Instability
	Labrum	Labral tear, degeneration, ossification
	Ligamentum teres	Ligamentum teres tear
III Contractile	Musculature crossing hip	Muscle strain
	Musculature crossing lumbosacral spine	Muscle tear
	Musculature crossing pelvic floor	Tendinopathy
IV Neuromechanical	Neurovascular structures	Nerve injury
	Axial/appendicular coordination and mechanics	Spine and lower extremity malalignment
		Pain syndromes

Table 2 Potential nerves injured and mechanisms during hip arthroscopy

Nerve	Mechanism
Pudendal	Pressure due to perineal post
Lateral femoral cutaneous	Direct injury due to portal placement
Common peroneal	Traction
Sciatic	Traction or portal placement
Femoral	Traction or portal placement
Superior gluteal	Portal placement

generators around the hip is paramount with regard to patient selection. The "layer concept" allows the hip surgeon to understand the pathology around the hip that may contribute to a patient's pain (Table 1) [12]. Unique complications encountered during arthroscopy are generally iatrogenic and related to the learning curve of the technique. These include, but are not limited to, iatrogenic chondrolabral injury, various motor and sensory neuropraxias (Table 2), skin damage due to excessive traction against the perineal post, and traction injuries to the foot and ankle. Complications encountered during open hip surgery are painful hardware, greater trochanteric pain syndrome, greater trochanteric osteotomy delayed/nonunion, heterotopic ossification (not unique to open surgery), avascular necrosis of the femoral head (although no reported cases in the literature for treatment of FAI with surgical hip dislocation), femoral neck fracture (not unique to open surgery), infection, and excessive blood loss.

Complications

Iatrogenic Chondrolabral Injury

The overall incidence of iatrogenic chondral and labral injury during hip arthroscopy is 3.8 % and 0.9 %, respectively, but have been reported to be as high as 20 % and 20 %, respectively [7, 13]. To obtain joint access, sharp instrumented joint entry is required for visualization, instrumentation, and mobilization. Unintentional injury to the labrum or articular cartilage may occur during initial portal placement from spinal needle entry, dilation, cannulation, or capsulotomy. During the early learning curve of hip arthroscopy, the rate of iatrogenic chondrolabral injury is greater with earlier time points [5]. Although there is published literature demonstrating that iatrogenic labral punctures have no significant effect on short-term clinical outcome [13], various studies have shown improved results with labral preservation compared to excision/debridement, and longer-term studies might shed further light on this subject [14–16]. Other recent investigations offer techniques to achieve a very low rate of chondrolabral injury (Table 3) [17, 18]. The latter recommend positioning the hip in mild flexion (15–20°), internal rotation, adduction, and traction to break the suction seal and achieve approximately 10 mm of distraction (Fig. 1). The safety of a blind anterolateral portal usually makes it the initial portal placed. A

Table 3 Step-by-step technique to reduce risk of iatrogenic chondrolabral injury [17]

Large-bore spinal needle joint entry with the bevel facing up to avoid the labrum
Stylet removed to permit an air arthrogram image
Stylet reinserted and the needle brought just outside of capsule
Fluoroscopically confirm needle outside of arthrogram
Reinsert needle back into joint with bevel facing labrum
As soon as "pop" is felt (penetration of capsule), needle rotated 180° to avoid femoral head articular cartilage
Stylet removed and nitinol wire placed intra-articular
Needle removed, followed by dilation, cannulation, and arthroscope insertion

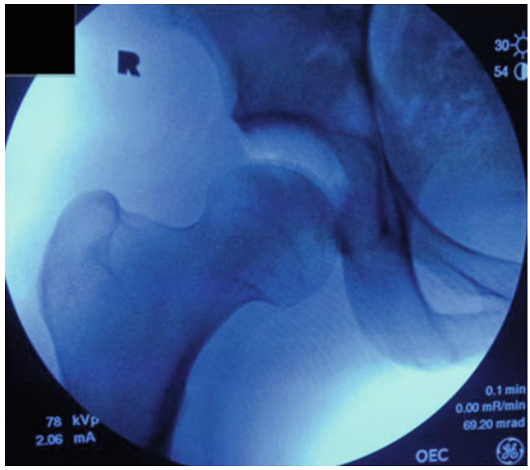

Fig. 1 Intraoperative *C*-arm fluoroscopy of a right hip in the supine position. A vacuum phenomenon is demonstrated after the suction seal is broken with application of traction

70° arthroscope is used to directly visualize extra-labral anterior portal placement. The arthroscope is switched to the anterior portal to verify that the anterolateral portal is extra-labral. The arthroscope is switched back to the anterolateral portal, and a transverse interportal capsulotomy is made. This step requires precision to avoid labral and chondral injury and to permit capsulotomy closure at the end of the procedure. Thus, the interportal capsulotomy should be made 5–10 mm from the labrum and 2–4 cm long, from approximately 10 to 2 o'clock for a left hip (Fig. 2), but the interportal capsulotomy may need to be extended depending on the size of the pincer deformity. Diagnostic arthroscopy of the central compartment can then be performed safely. Acetabuloplasty rim trimming and labral treatment are performed with the hip in traction. In cases with excessive rim over-coverage or in the presence of a large hypertrophic labrum, there is greater risk of iatrogenic chondrolabral injury, and making the capsulotomy from outside in or beginning in the peripheral compartment might allow for safer entry into the central compartment under direct visualization.

During labral refixation or reconstruction, the surgeon must be cognizant of the appropriate drill angle for anchor placement to avoid penetration through the acetabular cartilage into the joint. Using three-dimensional acetabular models of computed tomography scans of 20 cadaveric hips, the acetabular rim angle was defined and evaluated [19]. This angle quantifies the amount of acetabular bone available for drill bit and suture anchor penetration and creates a safety margin for the surgeon. Using drill bits of length between 10 and 25 mm and acetabular rim trimming amounts of 0, 2.5 and 5.0 mm, the investigation demonstrated that clock position, drill depth, and amount of rim trimming all had significant effects on the acetabular rim angle. The angle was greatest at 2 o'clock but smallest at 3 o'clock. While greater drill depth significantly reduced the rim angle, greater amounts of rim trimming significantly increased rim angle. Thus, anterosuperiorly, the surgeon must take care in drilling the minimum amount necessary to insert the anchor, especially near the 3 o'clock position. Ultimately making the portals used for placing anchors further distal typically gives a better angle for drilling and anchor placement with less risk for penetration of the acetabular articular cartilage. Beyond drilling and anchor placement, the surgeon must pass suture around or through the labrum. If suture retrieval is lost, this creates an opportunity for multiple passes of the suture-passing device through the labrum, which can potentially lead to biological disruption.

Iatrogenic Instability

There have been nine reported cases of post-arthroscopy hip dislocation [4, 20–25]. Due to publication bias, this is likely a significant

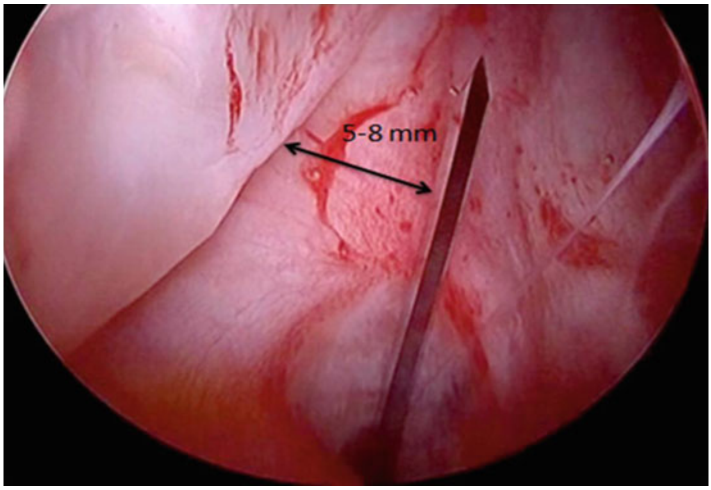

Fig. 2 Interportal capsulotomy creation may be made 5–8 mm from the acetabular labrum with an arthroscopic scalpel. This amount of acetabular side capsule permits tissue for capsular repair or plication at the conclusion of the case. The patient is in the supine position, with the right hip being viewed from the anterolateral portal

underestimate of the true incidence of instability following hip arthroscopy [7]. In addition, it is likely that a number of patients have persistent disability from subtle instability postoperatively without frank dislocation which is much more difficult to define (Figs. 3 and 4). The risk of postoperative instability is related to the following patient-, hip-, and surgical technique-specific factors: type and size of capsulotomy or capsulectomy without repair, labral resection (versus refixation or repair), overaggressive rim trimming, overall capsular laxity, and psoas tenotomies [10]. Capsulotomy (interportal with or without "T" extension) permits visualization and instrumentation of the central and peripheral compartments. However, the iliofemoral ligament is the strongest of four discrete hip ligaments, and its primary purpose is to restrain external rotation and extension of the hip. This part of the capsule is vital to stability in the latter provocative positions (Fig. 5). Multiple cadaveric biomechanical studies have demonstrated that iliofemoral ligament sectioning results in increased external rotation, extension, and anterior translation [26–28]. Further, no difference exists between the repaired and intact state. Thus, unrepaired capsulotomies have the potential for postoperative instability in some situations, which falls along a spectrum of "microinstability" to frank dislocation [29–32]. Although technically demanding, there are several pearls and pitfalls to assist the surgeon in performing repair or plication (Table 4). Following open hip preservation surgery, instability has not been reported in the literature. In this situation, capsulotomies are, for the most part, repaired once the intra-articular work is complete, reducing the risk of instability. It is imperative for the surgeon to have an understanding of normal acetabular anatomy, hip dysplasia, and dysplastic variants when performing FAI corrective procedures. Excessive rim resections should be avoided in all patients, and the capsule and labrum should be repaired/preserved in borderline dysplastic hips. Psoas tenotomies should also be performed with caution as psoas impingement is frequently seen in the setting of acetabular dysplasia and excessive femoral neck anteversion, both of which can be associated with anterior hip instability. Psoas tenotomies in the presence of anterior instability can further destabilize the hip. Prior studies have reported inferior outcomes after psoas tenotomy in the presence of excessive femoral neck anteversion as well as postoperative hip dislocation after psoas tenotomy and capsulotomy performed arthroscopically [33].

Neurovascular Injury

Nerve or blood vessel injury is uncommon during both arthroscopic and open hip surgery [7, 9]. In hip arthroscopy, the incidence of nerve damage is 1 %, with temporary (recovery room to 4 months following surgery) neuropraxia accounting for

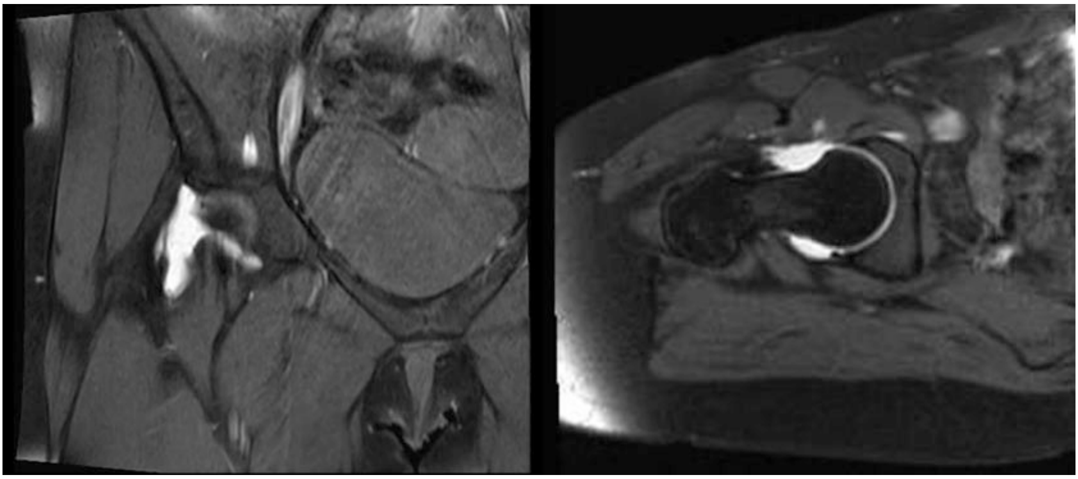

Fig. 3 MRA evidence of capsular defects after hip arthroscopy. *Left*: T2 coronal images demonstrating gadolinium extravasation due to capsular defect. *Right*: T2 axial oblique images demonstrating capsular defect with retraction of the iliofemoral ligament

Fig. 4 Arthroscopic evaluation of capsular defect involving the entire iliofemoral ligament

nearly all cases. The most commonly reported affected nerve is the pudendal (40 %), followed by lateral femoral cutaneous (21 %), sciatic (17 %), common peroneal (17 %), and femoral (4.7 %) [7]. The pudendal nerve (sacral plexus; S2–S4) is both a somatic and autonomic nerve that provides sensory, motor, sympathetic, and parasympathetic function to both male and female external genitalia and sphincters of the bladder and rectum. Nerve compression between the perineal post and the inferior pubic ramus may lead to a neuropraxia, with subsequent perineal numbness, and less commonly difficulty with erection and ejaculation [34]. Urinary and/or fecal incontinence have not been reported following hip arthroscopy, likely due to the relevant innervation of the structures controlling these functions proximal to the zone of compression and the fact that bilateral nerve injury would be required in order to cause incontinence [34]. Further, inferior pubic rami anatomy is unique between genders (steep course of ramus from ischial tuberosity to pubic symphysis in males versus more rounded, gentler, and straighter course in females) [34]. Although the magnitude of traction while using a perineal post has been shown to significantly affect the incidence of pudendal nerve injury, the effect of duration of traction is less clear [35]. Additionally, a lower extremity adduction moment increases the traction force [35] and the force around the post [36]. Therefore, in order to reduce the risk of pudendal nerve compression in the perineum, the following can be helpful: general anesthesia with muscle relaxation in particular when longer traction times are required, sufficient padding of the perineal post, joint distention, and application of the least amount of traction force necessary to distract the hip sufficiently (less than 50 lb) [37]

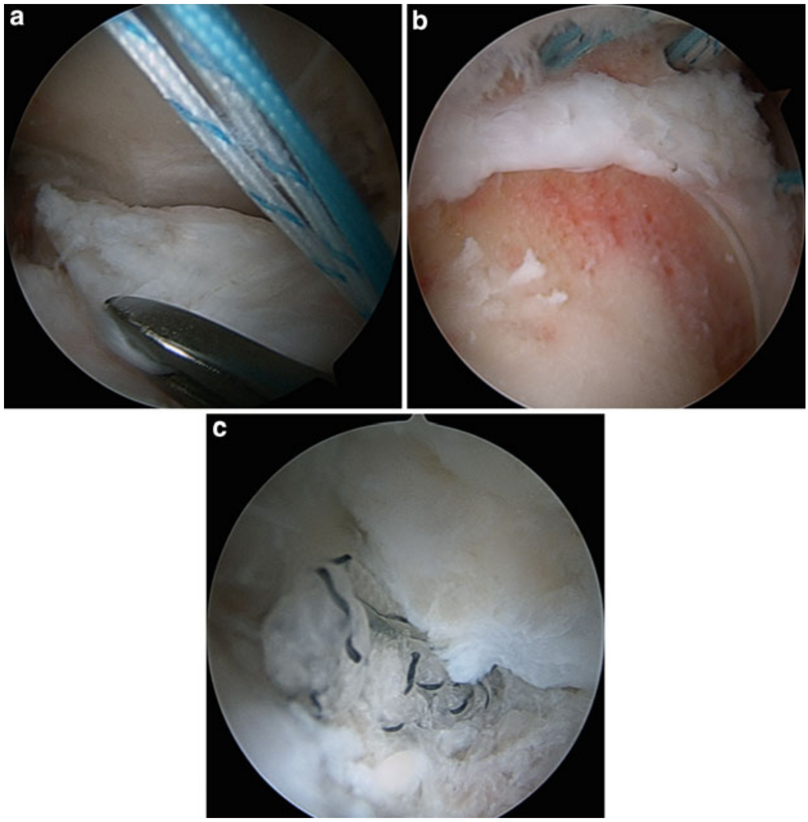

Fig. 5 (**a**) Arthroscopic view of the anterior aspect of the femoral neck. Using an arthroscopic grasper to mobilize the retracted iliofemoral ligament. (**b**) Arthroscopic revision femoral osteochondroplasty with three sets of double-loaded suture anchors for capsular reconstruction. (**c**) Arthroscopic view of the completed capsular reconstruction with suture anchors

Table 4 Pearls and pitfalls for hip capsulotomy and capsular repair or plication. DALA (distal anterolateral accessory) portal; IFL (iliofemoral ligament) [10]

Pearls	Pitfalls
Interportal and "T" capsulotomy	Poor visualization
Enhanced central and peripheral compartment visualizatio	Poor portal placement
Refixation of labrum	Failure to address bony pathology
Suture anchor based; as close as possible to articular margin using DALA portal	Femoral cam and acetabular pincer
Static stability restoration	Stresses labral/capsular repair
Femoral and acetabular osteochondroplasty	Too aggressive capsulectomy
Reduces/eliminates impingement	Prevents complete closure or requires too much tension upon repair that predisposes to stiffness postoperatively
Complete capsular closure	Damaged capsular edges from mechanical shaver devices may preclude secure "bite" with sutures
Avoid aggressive capsulectomy	Avoid iatrogenic articular cartilage damage with passage of tissue penetrator/suture passer devices
Begin closure at distal base of IFL "T'd" capsule and progress proximally toward interportal capsulotomy	Postoperative rehabilitation
Customize degree of plication/"bite" based on patient's ligamentous laxity status	Hip extension or external rotation that stresses capsulolabral repair, with potential disruption
Postoperative rehabilitation	Poor patient selection
Avoid hip extension, external rotation	Dysplasia, hyperlaxity, coxa magna

and adduction necessary to achieve joint visualization for the least amount of time. Some surgeons have even successfully performed arthroscopy without a perineal post [38].

Sciatic nerve (L4–S3) neurophysiologic monitoring during supine arthroscopy has revealed that approximately half (54 %) of subjects experience significant somatosensory evoked potential (SSEP) waveform changes [39]. These changes (signal loss) occur from 7 to 46 min from traction onset and are recovered after 2–15 min of traction release. The latter investigation's time dependency has not been observed during lateral arthroscopy, where SSEP and also tcMEP (transcranial motor evoked potential) have been used to study this phenomenon [40]. The risk of a sciatic nerve event significantly increased 4 % with every 0.45 kg increase in traction ($p = 0.043$), while an increase in traction time did not significantly increase the risk of a nerve event ($p = 0.201$). However, only 7 % of subjects had a clinically detectable postoperative nerve injury. Historically, the 2-h time limit on duration of hip arthroscopy traction was extrapolated from the time-dependent ischemia threshold associated with tourniquet use [41]. It appears that the time dependency of neural injury is related to the perineum and pudendal nerve due to a compression or ischemic effect while in the supine position versus the magnitude dependency of neural injury which is related to the sciatic nerve and axial distraction while in the lateral position [41]. Thus, the surgeon should be mindful of both traction magnitude, especially while lateral, and traction duration, especially while supine [41].

Sufficient padding of the lower extremity in order to reduce neural compression and injury applies to the foot and ankle boot as well, not just the perineum. The superficial peroneal nerve is at risk of compression injury if the foot/ankle is improperly padded and also if the duration/magnitude of traction is excessive [37]. Femoral nerve (L2–L4) injury has also rarely been reported, secondary to either traction, fluid extravasation, or excessively medial placement of the anterior portal [7]. The lateral femoral cutaneous nerve (L2–L3) is at risk with anterior arthroscopic portal placement and open anterior approaches to the hip due to its directly subcutaneous extrafascial location. Although the nerve course is variable, it tends to pass medial to the anterior superior iliac spine (ASIS), under the inguinal ligament, on the superficial surface of sartorius muscle approximately 10–15 mm distal to the ASIS [42]. This places the nerve proper or one of its branches in very close proximity to a deep stab incision for anterior portal placement. Lateral femoral cutaneous nerve injury may cause a spectrum of symptoms ranging from benign or bothersome numbness to debilitating painful dysesthesias. Lateral femoral cutaneous neuropraxia is likely underreported, as the majority may not be noticed by the patient and found on inspection of the anterolateral thigh with nearly all resolving within 6 months post-surgery. The superior gluteal nerve limits the safe zone of the anterolateral and posterolateral portals proximally at approximately 4–7 cm [43, 44]. The sciatic nerve limits the safe zone of the posterolateral portal posteriorly at approximately 2–5 cm [43, 44]. Thus, avoidance of hip external rotation is recommended as the greater trochanter moves posteriorly blocking access for the portal and putting the nerve at greater risk.

The most common vascular structure at risk for injury anteriorly is the ascending terminal branch of the lateral femoral circumflex artery, which may be as close as 10 mm from an anterior portal [44]. However, this artery is commonly ligated during a Smith-Peterson approach just deep to the interval between the tensor fascia lata and sartorius. Due to the fact that the medial femoral circumflex is the largest contributor to the head, lateral femoral circumflex injury or ligation is likely of minimal consequence [45]. During surgical hip dislocation, when preparing to perform greater trochanteric osteotomy, it is critically important to protect the medial circumflex vessels by leaving the external rotators intact. These small muscles should remain attached to the non-osteotomized femur. When dissecting near the insertion of the external rotators on the proximal femur, the surgeon must identify the superior margin of quadratus femoris, which is marked by the trochanteric branch of the deep branch of the medial circumflex artery [45]. The trochanteric branch marks the level of the tendon of the obturator externus, which is crossed posteriorly by the deep branch of the medial circumflex. The obturator externus is responsible for protecting this vessel from either tension or compression during surgical hip dislocation. The deep branch ascends superiorly and pierces the capsule at the level of the superior gemellus. Once intracapsular, 2–4 subsynovial superior retinacular vessels pierce the head approximately 2–4 mm from the head-neck junction. Damage to the medial femoral circumflex artery or one of its branches may cause variable degrees of femoral head avascular necrosis. Following hip arthroscopy, the risk of avascular necrosis is less than 1 % (10 cases reported out of 6,334 hips) [7]. Following surgical dislocation, the risk is also significantly less than 1 % [9]. However, the intent of the surgery is to access 360° of the femoral head and acetabulum with a 0 % risk (not just less than 1 %) of avascular necrosis, implying that this complication is completely preventable with attention to appropriate technique [46]. Although avascular necrosis has been reported following surgical hip dislocation for the treatment of Perthes disease, slipped capital femoral epiphysis, and developmental hip dysplasia [47], it has not been reported for the treatment of femoroacetabular impingement. It must be recognized, however, that the surgeons performing these techniques are experienced surgeons that either developed the technique or have trained with the developers, performed hip vascular supply research with the developers, and performed a high volume of the technique. The femoral artery proper is at risk only with far medial straying of the anterior portal (3.5–4 cm medial).

Heterotopic Ossification

Heterotopic ossification may complicate the postoperative outcome after hip preservation surgery. Open approaches have significantly higher rates of heterotopic bone formation versus arthroscopic approaches although in the majority of cases it is not clinically relevant [9]. In a recent systematic review of 29 studies and over 2,500 hips, the rate of heterotopic ossification following surgical dislocation was 15 %, followed by mini-open (13 %), arthroscopic plus mini-open (3 %), and arthroscopy (<1 %) ($p < 0.05$) [9]. The use of the Brooker grading system revealed that most cases are grade 1 (72 %), followed by grade 2 (20 %), grade 3 (7 %), and grade 4 (1 %). Neither prophylaxis nor treatment was discussed for management of the ectopic bone formation in most studies. However, in the studies that did report the presence or absence of symptoms, the majority of subjects did not require further treatment, as the mild grades of ossification were largely not bothersome (Figs. 6 and 7).

Heterotopic ossification prophylaxis has been studied in two recent large investigations. In a retrospective comparative case series of 300 subjects with 18-month outcome after hip arthroscopy, the use of oral nonsteroidal anti-inflammatory drug (NSAID) prophylaxis was evaluated (naproxen 500 mg twice daily for 3 weeks in 248 subjects; indomethacin, ketoprofen, or etoricoxib for 3 weeks in 37 subjects) [48]. Fifteen subjects received no NSAID prophylaxis (control). Five cases of heterotopic ossification occurred following surgery, and all were in the control group (33 % rate without prophylaxis). No heterotopic ossification occurred if the patient received prophylaxis. In a separate comparative cohort study of 616 subjects after hip arthroscopy for FAI or peritrochanteric disorders, the addition of indomethacin (Indocin SR, Merck, Whitehouse Station, New Jersey, USA; 75 mg orally once daily for 4 days) to a naproxen-only (500 mg orally twice daily for 30 days) protocol reduced the risk of heterotopic ossification from 8.3 % to 1.8 % ($p < 0.05$) [49]. The latter analysis showed that patients that received only naproxen following surgery were 4.4 times more likely to develop ectopic bone formation. All cases of heterotopic ossification occurred in the setting of osteoplasty for FAI. One percent of subjects needed revision surgery for excision of heterotopic bone. Of note, patients receiving indomethacin also received omeprazole (20 mg orally once daily for 4 days following surgery) for gastric protection. Patients that develop heterotopic ossification are more

Fig. 6 A 20-year-old collegiate soccer player 1-year status post hip arthroscopy with heterotopic ossification. *Left*, pre-op. *Right*, post-op

Fig. 7 Arthroscopic removal of heterotopic ossification

frequently male (80 % in the former and 72 % in the latter studies) [48, 49]. Removal of all bony debris and coagulation of vessels within the periarticular muscles at the conclusion of FAI corrective procedures might also decrease the potential for HO development.

Other Minor Complications

Skin injury following hip arthroscopy is uncommon, with an incidence of 0.16 % (10 cases out of 6,334 hips; 6 labial and/or vaginal and 4 scrotal) [7]. Reduction in the duration and magnitude of traction, placement of a large (greater than 9 in. diameter to distribute pressure) perineal post more lateral (on the medial thigh) than central in the perineum, and visualization of safety of external genitalia upon traction initiation without any excessive pressure or malpositioning may reduce the already low incidence of skin injury following hip arthroscopy.

The rate of postoperative superficial infection (requiring only antibiotic therapy without surgery) is very low following hip arthroscopy (0.11 %). Only one case of septic arthritis requiring surgical arthrotomy and drainage has been reported in the literature following hip arthroscopy [50]. Despite a larger incision, the rate of infection following open approaches for hip preservation is very low and not significantly different from that of arthroscopy [9]. The deep nature of the hip mandates longer instruments with longer lever arms to visualize and instrument the joint. Thus, instrument breakage is a potential adverse event that is uncommon (9 cases out of 6,334 reported) [7] but largely preventable with safe, meticulous, and non-forceful cannulation and instrumentation. Although stiffness following hip preservation surgery is not commonly reported, the rate of lysis of adhesions for post-arthroscopic arthrofibrosis is 0.47 % [7].

Other Rare, but Severe, Complications

Despite their infrequency, rare complications that are potentially harmful to life or limb merit specific consideration, and steps should be taken to avoid them at all costs. Following hip preservation surgery (either open or arthroscopic), only two deaths have been reported (one in a polytrauma patient due to pulmonary embolus [51] and the other "an unrelated cause") [7, 9]. Despite extensive guidelines by multiple organizations in different fields of medicine regarding thromboembolic disease and its prophylaxis following hip arthroplasty, the literature following hip preservation surgery is scarce. Following both arthroscopic and open surgery, the literature contains only isolated case reports of superficial and deep vein thromboses and/or pulmonary emboli [7, 9]. The only guidelines published for hip arthroscopy thromboembolic disease prevention were released by the Italian Intersociety Working Group [52]. Despite no studies to support guidelines, the workgroup recommended thorough preoperative assessment of thrombophilic and bleeding risk factors and postoperative use of mechanical (compression stockings, intermittent sequential compression devices) and pharmacologic (low-molecular-weight heparin) measures for patients undergoing arthroscopy. Although the current rates of thromboembolic events after hip arthroscopy do not support the routine use of DVT prophylaxis, one might consider this for patients with significant risk factors such as those with clotting cascade disorders and those traveling long distances or flying in the early postoperative period.

Following femoral head-neck junction cam osteochondroplasty, there have been only five cases of proximal femur fracture reported in the literature. Three cases occurred following arthroscopy (all with femoral osteochondroplasty), with two being successfully treated nonoperatively and one requiring reduction and sliding hip screw fixation [4, 53, 54]. One subtrochanteric femur fracture has been reported following mini-open femoral osteochondroplasty, and one femoral neck fracture has been reported following arthroscopic-assisted mini-open femoral osteochondroplasty [9]. Regardless of the type of approach used, basic science literature has demonstrated up to 30 % of the femoral neck diameter may be removed without increased risk of fracture [55]. While fracture is rare and the optimal resection amount is still unknown, the surgeon must be cognizant that over-resection or resections in the presence of relatively osteopenic bone may increase the risk of fracture.

Intra-abdominal or intrathoracic extravasation of fluid may lead to abdominal compartment syndrome, cardiovascular collapse, and death. This complication is exclusively related to arthroscopy. Twenty-two cases have been reported in the literature (19 intra-abdominal; 3 intrathoracic) [7]. One of these patients did experience transient, yet prolonged, asystole, with subsequent successful resuscitation [56]. This was a case of a trauma patient with an acetabular fracture in which fluid extravasated through the fracture. This did require emergent exploratory laparotomy and decompression. A second case exhibited temporary apneic pulseless electrical activity that only responded to emergent laparotomy and decompression [57]. The other reported cases have demonstrated risk factors of longer operative time and performance of iliopsoas release [37, 58]. Thus, keeping intra-articular pressure as low as possible, performing the surgery as efficiently as possible without compromising quality, frequently monitoring the abdomen and peek ventilatory inspiratory pressure, and performing iliopsoas releases when indicated at the conclusion of the case might help to minimize the risk for this complication.

Classification Systems in Orthopedic and Hip Preservation Surgery

The lack of clear definitions and classification of complications in orthopedic surgery prompted the ANCHOR group to adapt the validated the Clavien-Dindo classification system to hip preservation surgery [8]. The original Clavien system was a four-grade classification used to assess complications following cholecystectomy [59]. This was modified by Dindo to a five-grade system, now utilized by general surgery and urology (Table 5) [60]. Ten hip surgeons from eight centers

Table 5 Modified Clavien-Dindo complication classification system [8]

	Definition	Example
Grade I	Requires no treatment	Asymptomatic heterotopic ossification
	Has no clinical relevance	Mild postoperative fever
	No deviation from routine follow-up	Simple wound problem not requiring intervention
Grade II	Deviation from normal postoperative course	Additional clinic visits
		Oral antibiotic treatment for superficial infection
	Requires outpatient treatment	Transient asymptomatic neuropraxia
Grade III	Treatable but requires surgical intervention	Deep infection requiring drainage
		Trochanteric nonunion requiring fixation
Grade IV	Life-threatening complication	Permanent nerve injury
	Requires intensive care unit	Avascular necrosis
	May result in permanent disability	Pulmonary embolism
Grade V	Death	

in three countries adapted the modified system to hip preservation surgery and reported a high inter- and intraobserver reliability [8]. The aim of the latter was to standardize the reporting of complications, improve the quality of evidence, and allow for valid comparison of outcome studies.

Summary

Recognition of femoroacetabular impingement as a potential precursor to hip osteoarthritis has led to the development of the field of both open and arthroscopic hip preservation within orthopedic surgery. The use of hip arthroscopy is rapidly increasing internationally. There is a significant learning curve associated with hip arthroscopy. The rate of minor complications is low (7.5 %) and is largely related to the learning curve. The two most common minor complications are iatrogenic chondrolabral injury and temporary neuropraxia. Although the rate of minor complications is higher following open surgical hip dislocation due to the development of painful hardware requiring removal, the rate of major complications is less than 1 % in both open and arthroscopic hip preservation surgeries. Lack of clarity in reporting complications within orthopedic surgery has spurred academic hip surgeons to adapt and test a general surgery-validated complication reporting system for use in hip preservation.

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