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Capsular thinning on magnetic resonance arthrography is associated with intra-operative hip joint laxity in women

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ABSTRACT

Hip microinstability is a recognized cause of hip pain in young patients. Intra-operative evaluation is used to confirm the diagnosis, but limited data exist associating magnetic resonance arthrography (MRA) findings with hip microinstability. To determine if a difference exists in the thickness of the anterior joint capsule and/or the width of the anterior joint recess on MRA in hip arthroscopy patients with and without an intra-operative diagnosis of hip laxity. Sixty-two hip arthroscopy patients were included in the study. Two musculoskeletal radiologists blinded to surgical results reviewed the MRAs for two previously described findings: (i) anterior joint capsule thinning; (ii) widening of the anterior joint recess distal to the zona orbicularis. Operative reports were reviewed for the diagnosis of joint laxity. In all patients with and without intra-operative laxity, there were no significant differences with either MRA measurement. However, twenty-six of 27 patients with intra-operative laxity were women compared with 11 of 35 patients without laxity ($P < 0.001$). In subgroup analysis of women, the intra-operative laxity group had a higher rate of capsular thinning compared with the non-laxity group (85% versus 45%; $P = 0.01$). A 82% of women with capsular thinning also had intra-operative laxity, compared with 40% without capsular thinning ($P = 0.01$). There were no differences regarding the width of the anterior joint recess. In this study, there was an association between capsular thinning and intra-operative laxity in female patients. Measuring anterior capsule thickness on a pre-operative MRA may be useful for the diagnosis of hip microinstability.

INTRODUCTION

Hip microinstability is frequently defined as extraphysiologic hip motion that results in pain, with or without the sensation of instability [1]. Hip microinstability has become increasingly recognized as a significant cause of nonarthritic hip pain and dysfunction in young patients and athletes [2–15]. While the diagnosis and management of gross hip instability has been well described [16], hip microinstability remains more poorly defined with a lack of consistent objective diagnostic criteria [7, 15].

One of the proposed mechanisms for the development of hip microinstability involves subtle anatomic abnormalities in conjunction with repetitive hip rotation and axial loading [1, 7, 16]. This abnormality in loading can not only lead to acetabular labrum and cartilage damage, but the repetitive microtrauma to the capsule can result in capsular laxity [7, 17]. While several physical examination tests and radiographic parameters associated with hip microinstability have recently been described, determining the underlying etiology and pre-operative diagnosis remains difficult [5, 7, 10, 15, 17, 18]. Even when considering patients with borderline dysplastic hips based on the lateral center edge angle, it is often unclear whether the underlying problem is due to impingement or dysplasia, and whether the patient would benefit from a surgery to correct cam-type impingement versus acetabular re-orientation [13, 19]. Intra-operative evaluation is frequently used to confirm the diagnosis of hip microinstability, however, the pre-operative identification would be beneficial for the discussion of treatment options and pre-operative planning [2–4, 8, 11, 14, 20–22].

Magnetic resonance arthrography (MRA) of the hip joint is useful in identifying many intra- and extra-articular causes of hip pain [17, 18]. Magerkurth *et al*. reported on a retrospective, single institution study of 27 patients evaluating MRA criteria for hip laxity [17]. They demonstrated that hip laxity was associated with an anterior capsular thickness <3 mm and an anterior hip joint recess >5 mm [17]. However, this study had a small sample size and there was no standardized volume of contrast injected.

At our institution, a pre-operative MRA with an injection of a standardized 12 ml of contrast solution is routinely performed to evaluate patients with hip pain. The primary objective of this study was to determine if a difference exists in the thickness of the anterior hip joint capsule and the width of the anterior hip joint recess on MRA in those with and without an intra-operative diagnosis of hip joint laxity. We hypothesized that thinning of the hip joint capsule and widening of the anterior hip joint recess would be observed in patients with an intra-operative diagnosis of hip laxity.

MATERIALS AND METHODS

This retrospective study was approved by our Institutional Review Board (IRB). One hundred fifty-three consecutive hip arthroscopy patients of the senior author (M.R.S.), a fellowship trained orthopedic surgeon, were identified between 1 July 2012 and 5 June 2013. Only patients with a pre-operative MRA performed at our institution were included in the study. All patients with pre-operative imaging performed at a different institution, previous hip surgery, pigmented villonodular synovitis, synovial chondromatosis or any tumor were excluded.

Since the current gold standard for the diagnosis of hip laxity is intra-operative confirmation, the operative reports for all included patients were reviewed for evidence of hip laxity. Every patient was evaluated for hip joint laxity at the beginning of the surgery. Hip laxity was defined by either (i) a minimal amount of traction required to distract the hip joint (often body weight) or (ii) the lack of hip reduction after release of negative intraarticular pressure and traction prior to the start of hip arthroscopy. Capsular plication was performed on all patients diagnosed with hip laxity.

Arthrography technique

A fluoroscopy-guided intra-articular contrast injection was performed in the standard fashion by one of the six fellowship-trained musculoskeletal (MSK) radiologists. The patients were placed supine on a fluoroscopy table and the hip was stabilized in mild internal rotation with the toes taped together. Local anesthesia was achieved with roughly 3 ml of 1% lidocaine. A 22-gauge spinal needle was advanced into the hip joint. The intra-articular position of the needle tip was confirmed with small injection of Omnipaque-240 contrast ([iohexol, 240 mg of iodine per ml]; GE Healthcare, Cork, Ireland). A standard mixture of dilute contrast including 0.1 ml gadodiamide (Omniscan; GE Healthcare; final concentration of 2.0 mmol/l); 4 ml of lidocaine, 10 mg/ml (Hospira, Lake Forest, IL); 7 ml of Ropivacaine, 5 mg/ml (Naropin; APP Pharmaceuticals, Schaumburg, IL, USA); 3 ml Omnipaque-240; 12 ml of 0.9% saline solution was injected into the hip joint. A total of 12 ml of the contrast solution was injected under fluoroscopic guidance into the hip joint.

Magnetic resonance imaging technique

All exams were performed on a 3-T MR scanner (Signa HDx, GE Healthcare) using an eight-channel, phased-array surface coil. The imaging protocol consisted of: axial T1-weighted imaging (TR/TE, 600–800/6–8), coronal T1-weighted imaging with fat saturation (TR/TE, 600–800/6–8), coronal proton density-weighted imaging with fat saturation (TR/TE, 4000–5000/35–50), axial oblique T1-weighted imaging with fat saturation (TR/TE, 600–900/8–10) and sagittal T1-weighted imaging with fat saturation (TR/TE, 800–1000/8–10) with the following parameters: matrix, 384 × 224; FOV, 20–22 cm; flip angle, 90°; slice thickness, 3 mm and interslice gap, 0.3 mm.

Image analysis

An MSK radiologist and an MSK radiology fellow blinded to surgical results reviewed the MR arthrograms for two morphologic findings that have been associated with hip joint laxity: (i) thinning of the anterior joint capsule (<3 mm) and (ii) widening of the anterior hip joint recess (>5 mm, Fig. 1) [17]. The axial T1 sequence, without fat suppression, was chosen because of the improved imaging contrast between the capsule and the adjacent fat compared with the fat suppressed sequences. The level used was the first level (from inferior) that showed the femoral neck bridging the femoral head and the capsular attachment onto the greater trochanter (Fig. 1). Measurements were made using the PACS measurement tool (Centricity PACS; GE Healthcare). Adjustment of image size (zoom), window width and window level was allowed.

Statistical analysis

Each independent measurement or categorical variable was compared with the presence or the absence of intra-operatively diagnosed hip laxity. Continuous variables between the two patient groups were analyzed with two-tailed unpaired *t*-test [23]. All categorical variables were compared using a χ^2 test [23].

RESULTS

During the study period, 62 patients met the inclusion criteria (Table I). Thirty-seven of the 62 patients were female (60%) and 25 were male (40%). Overall, 27 patients (44%) were diagnosed intra-operatively with hip laxity and 35 patients (56%) did not have hip laxity. Regarding gender, 26 of the 37 females (70%) had hip laxity compared with 1 of the 24 male (4%) patients ($P < 0.001$). The average age of patients with and without hip laxity was 31.7±9.4 and 34.7±12.7 years, respectively ($P = 0.31$).

When evaluating anterior hip joint capsular thickness, the average for those with and without hip laxity was 2.2 and 2.3 mm, respectively ($P = 0.34$; Table I). When specifically looking at females, the average capsular thickness in patients with and without hip laxity was 2.0 and 2.4 mm, respectively ($P = 0.26$). Twenty-two of the 26 females (85%) with intra-operative hip laxity had <3 mm of anterior capsular thickness compared with 5 of the 11 females (45%) without intra-operative laxity ($P = 0.01$, Fig. 2). In the 27 female patients with an anterior capsular thickness of <3 mm on MRA, 22 (82%) had intra-operative hip laxity. However, in the 10 female patients with >3 mm of anterior capsular thickness on MRA, only 4 (40%) were diagnosed with hip laxity ($P = 0.01$, Fig. 3).

The mean width of the anterior hip joint recess in those with and without hip laxity was 5.6 and 5.7 mm, respectively ($P = 0.95$, Table I). When specifically evaluating female patients, the average width of the anterior hip joint recess in those with and without hip laxity was 5.6 and 5.5 mm, respectively ($P = 0.87$). In the 26 female patients with intra-operative hip laxity, 18 (69%) had >5 mm of width in the anterior hip joint recess compared with 7 of the 11 (64%) female patients without intra-operativelaxity ($P = 0.74$, Fig. 2). Twenty-two of the 26 females (85%) with intra-operative hip laxity had either anterior capsular thickness <3 mm or anterior hip joint recess width >5 mm. Seven of the 11 women (64%) without intra-operative hip laxity had anterior capsular thickness <3 mm or anterior hip joint recess width >5 mm ($P = 0.16$, Fig. 2). Sixty-nine percent of female patients with hip laxity had anterior capsular thickness <3 mm and anterior hip joint recess width >5 mm, compared with 45% of female patients without hip laxity ($P = 0.17$, Fig. 2).

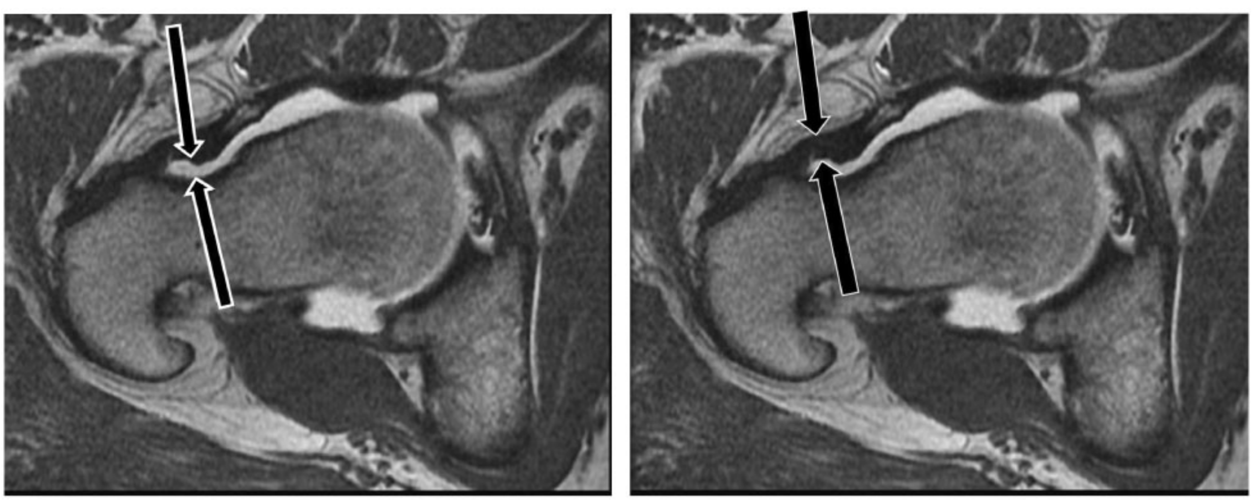

Fig. 1. Representative MRA image of the anterior hip joint capsule thickness and width of the anterior hip joint recess. A right-sided T1-weighted axial image without fat suppression after intra-articular administration of dilute contrast demonstrating location of measurements of the thickness of the anterior hip joint capsule (left image) and the width of the anterior hip joint recess (right image).

Table I. Patient's characteristics in those with and without hip joint laxity

Population characteristics	*Hip laxity* (N = 27)	*No hip laxity* (N = 35)	P-*value*
Age (years)	31.7 ± 9.4	34.7 ± 12.7	0.31
Female (*n*)	26	11	<0.001
Male (*n*)	1	24	
Avg. capsular thickness	2.2 mm	2.3 mm	0.34
Avg. anterior recess width	5.6 mm	5.7 mm	0.95

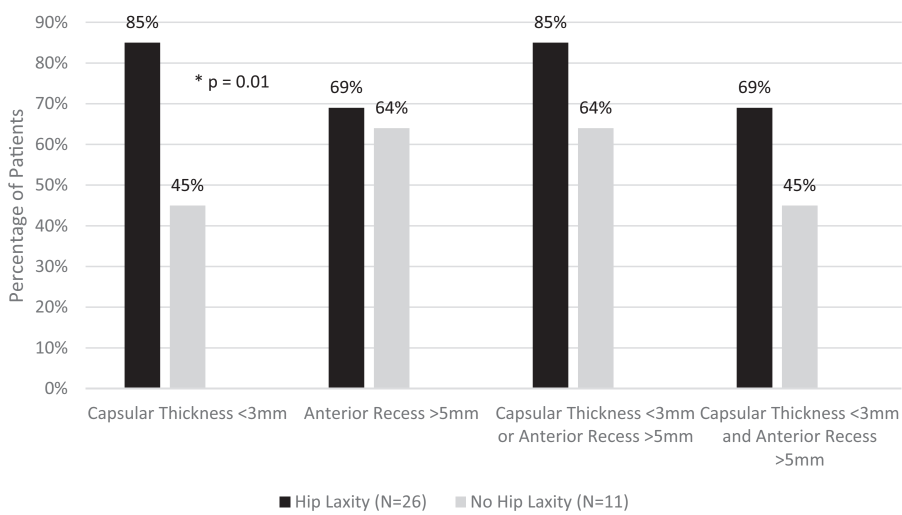

Fig. 2. Comparison of MR findings in female patients with and without hip joint laxity.

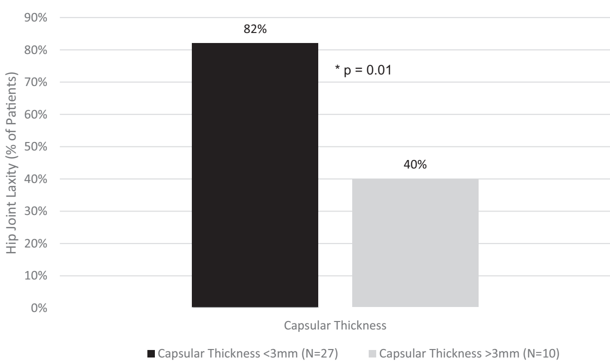

Fig. 3. Comparison of capsular thickness <3 and >3 mm in female patients with hip joint laxity.

DISCUSSION

Hip microinstability with hip joint laxity (presumably due to capsular laxity) has been identified as an increasingly known etiology of non-arthritic hip pain in young, active patients [2–14, 17]. Given that good outcomes can be achieved with arthroscopic and open capsular plication techniques, there is a need to develop pre-operative criteria for the diagnosis of hip microinstability [2–4, 8, 14, 17, 20, 21, 24, 25]. The purpose of this study was to determine if a difference exists in the thickness of the anterior hip joint capsule or the width of the anterior hip joint recess based on previously described MRA measurements in patients with and without an intra-operative diagnosis of hip laxity. The importance of this study is to help identify pre-operative parameters that may aid in the diagnosis of hip microinstability. We hypothesized that thinning of the hip joint capsule and widening of the anterior hip joint recess would be observed in patients with hip laxity. In this study, we demonstrated that laxity of the hip joint was associated with anterior capsular thinning <3 mm in female patients, but did not correlate with anterior hip joint recess width >5 mm.

Historically, the hip joint was viewed to be a highly constrained 'ball and socket' secondary to its bony anatomy, however, numerous authors have recently reported on the importance of the hip capsuloligamentous complex on hip joint stability [7, 17, 26–29]. This capsuloligamentous complex consists of five main components, the iliofemoral ligament, pubofemoral ligament, ischiofemoral ligament, ligamentum teres and the zona orbicularis [7, 28, 30, 31]. The iliofemoral is the strongest of these ligaments, comprising a portion of the anterior joint capsule and its shape is an inverted Y with a single proximal attachment at the base of anterior inferior iliac spine [1, 7, 32]. As this ligament traverses distally, it splits with a lateral arm attachment on the anterior prominence of the greater trochanter and a medial arm attachment on the anterior femur at the level of the lesser trochanter [1, 7, 32]. It has been demonstrated that the iliofemoral ligament provides the main restraint to external rotation in all hip positions along with internal and external rotation restraint with the hip in an extended or neutral position [33].

Many potential etiologies of hip microinstability exist and include bony abnormalities, connective tissue disorders, trauma, microtrauma such as associated with athletics, iatrogenic (prior hip arthroscopy) and idiopathic [15]. When the capsuloligamentous complex, including the iliofemoral ligament, is stretched or torn, pathologic capsular laxity with hip microinstability can ensue [10, 11]. In the absence of osseous deformities, such as hip dysplasia, or connective tissue disorders, the diagnosis of hip microinstability can be difficult and requires a high degree of suspicion [1, 7, 10]. In the evaluation of patients for microinstability, six provocative physical examination maneuvers have been described: (i) hyperextension-external rotation test (anterior apprehension test), (ii) prone external rotation test (prone instability test), (iii) abduction–hyperextension–external rotation test, (iv) posterior apprehension test, (v) log roll test and (vi) axial distraction test [5, 10]. In a recent study by Hoppe *et al.*, it was demonstrated that if the first three of the aforementioned tests are positive, then there is a 95% likelihood that the patient will have an intra-operative diagnosis of hip microinstability [5].

While the history and the physical examinations are important in the evaluation of microinstability patients, there is a need for objective pre-operative imaging criteria [10]. A radiographic finding called the cliff sign was recently described and was associated with the intra-operative diagnosis of microinstability [10]. The cliff sign is defined as a steep drop-off from a perfect circle in the lateral aspect of the femoral head [10]. Among the 96 patients in the cohort, 74% with a positive cliff sign had microinstability compared with only 12% of patients who had a negative cliff sign [10]. In a study by Magerkuth *et al.*, 27 patients who had intra-operative documentation of the presence or the absence of hip laxity and a pre-operative MRA were retrospectively reviewed to determine if unique imaging qualities are associated with capsular laxity [17]. In their study, they demonstrated that patients with capsular laxity had increased anterior hip joint capsule width lateral to the zona orbicularis >5 mm and capsular thinning in the same location <3 mm [17].

In this study, we demonstrated that female patients with hip laxity had a significantly higher rate of anterior capsular thinning (width <3 mm) compared with female patients without laxity. However, in contrast to the Magerkuth study, we did not find any differences in the rate of anterior capsular recess widening (width >5 mm) when comparing patients with and without hip laxity, including when analyzing a subgroup of female patients. A possible explanation for this difference is that in our study, the MRA technique was controlled so that all patients had 12 ml of solution injected into the hip joint. In the study by Magerkuth *et al.*, it was noted that 10–14 ml of dilute contrast was injected, based on when the patients would first mention tension in the hip joint [17]. By using the sensation of hip joint tension rather than a specific injection volume, the differences in volume injected may confound the anterior capsular recess width measurement. On the other hand, it is possible that our fixed injection volume of 12 ml may have caused different degrees of hip joint distention based on the size of the patient's hip joint. For example, a patient with a smaller hip joint may have greater distention with a 12 ml injection than a patient with a larger hip joint. This could explain why there were no differences in the anterior capsular recess width measurement in our cohort. The anterior capsular thickness, however, would be independent of the relative volume of contrast injected.

In this study, hip laxity was almost exclusively seen in female patients (96% of all microinstability patients—the one male was a professional ballet dancer). This finding is consistent with the findings of previous studies, which also found a much higher prevalence of hip microinstability in the female population [8, 10]. When evaluating the association between the cliff sign and hip microinstability, 100% of female patients under the age of 32 who had a positive cliff sign also had microinstability [10]. Similarly, when Kalisvaart *et al.* [8] evaluated the efficacy of capsular plication in the treatment of hip microinstability, their entire study population of 32 patients were females. A possible explanation for these observations is that, in addition to the bony and capsuloligamentous architecture of the hip joint, stability is also provided by the peri-articular soft tissues and muscle [29].

Strengths of this study include a large study cohort of 62 patients including 37 women, standardized MRA injections at 1 institution, and the intra-operative evaluation of every hip arthroscopy patient for hip joint laxity. Limitations of the present study include its retrospective design and the inherent limitations with retrospective studies. Additionally, the study cohort consisted of a single surgeon's hip arthroscopy patients, and the diagnosis of microinstability was based on a subjective intra-operative assessment. However, based on current knowledge, the best technique for the diagnosis of hip microinstability was used, and these criteria have been published elsewhere [8, 10, 11, 22]. Another limitation is that the senior author receives a significant number of referrals for patients with suspected microinstability and therefore may treat a larger proportion of microinstability patients compared with the general population. Despite these limitations, this study represents the largest cohort of hip arthroscopy patients who were evaluated with preoperative MRA for capsular and anterior recess measures as well as intra-operative hip laxity. Future research could evaluate the combination of reported physical examination, radiographic and MRA characteristics associated with hip microinstability. Studying these factors together may allow the development of a diagnostic model to aid in pre-operative management and surgical decision-making.

CONFLICT OF INTEREST STATEMENT

None declared.

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