Skeletal Radiology (2019) 48:889–896
https://doi.org/10.1007/s00256-018-3083-5

SCIENTIFIC ARTICLE

Iliopsoas snapping hip: improving the diagnostic value of magnetic resonance imaging with a novel parameter

Wajeeh Bakhsh [1] · Sean Childs [1] · Raymond Kenney [1] · Scott Schiffman [2] · Brian Giordano [1]

Received: 20 May 2018 / Revised: 8 September 2018 / Accepted: 23 September 2018 / Published online: 2 October 2018

Abstract

Objective To illustrate an advanced imaging parameter that describes the course of the iliopsoas tendon, and evaluate its correlations with iliopsoas internal hip snapping syndrome.

Methods This retrospective cohort study reviewed hip MRI images of all patients seen by a single surgeon between January 2015 and March 2016. The comparison group included all patients with clinical internal hip snapping, versus the control group that did not. MRI images were processed using minimum intensity projection. Measurements obtained of the pelvis and course of the iliopsoas tendon included: pelvic incidence, coronal angle, and sagittal opening angle (SOA). Comparison of measurements between the groups was performed with Mann–Whitney U analysis and receiver operator curve (ROC) plotting, with a significance cutoff of $p = 0.05$.

Results The control group ($n = 85$) and comparison group ($n = 48$) demonstrated no difference in age or gender. Pelvic incidence was similar [51.3 (± 10.7) degrees control versus 52.2 (± 7.7) degrees comparison ($p = 0.36$)], as was coronal angle [13.9 (± 4.6) degrees control versus 14.8 (±4.8) degrees comparison ($p = 0.15$)]. There was a significant difference in SOA [137.0 (± 5.9) degrees control versus 141.9 (± 6.5) degrees comparison ($p < 0.01$)]. ROC analysis revealed SOA threshold of 140 degrees for clinical IP hip snapping ($p < 0.01$), with odds ratio 5.2 (2.4–11.3) for SOA > 140 degrees.

Conclusions Iliopsoas hip snapping is often part of a more complex disease process. While challenging to diagnose, advanced imaging parameters, like the sagittal opening angle, relate with clinical pathology. The SOA offers diagnostic value, with a threshold of greater than 140 degrees significantly correlating with clinical presentation.

Keywords Iliopsoas · Hip snapping · MRI · MIP · Sagittal opening angle

Introduction

Coxa saltans, or auditory snapping with hip movements, is a common musculoskeletal complaint seen in 5–10% of the general population [1]. There is no significant difference in gender, although these symptoms are more common in elite athletes, especially with hip flexion beyond 90 degrees [2]. Generally, pain associated with this syndrome is aggravated by activities including flexion and rotation [3, 4]. This painful snapping often interferes with activity, and requires orthopedic evaluation. Typically, these symptoms improve with nonoperative measures including but not limited to stretching, physical therapy, nonsteroidal anti-inflammatory medications (NSAIDs), activity modification, and local anesthetic injection [5]. If these measures fail, surgical lengthening of the offending tendon or debridement of the appropriate pathology has been shown to provide relief [6]. Approximately one-third of patients present with symptomology that is unresponsive to conservative management; surgical intervention has a variable success rate, but largely greater than 80% [7, 8].

Hip snapping is classified by pathology, whether intra- or extra-articular. Intra-articular pathology, such as a labral tear, cartilage defect, loose body, or osseous fragment can present with audible snapping that accompanies hip movement [9]. Extra-articular sources of pathology that present similarly include either the iliotibial (IT) band or iliopsoas (IP) tendon. The IT band "snaps" as it moves over the lateral hip or greater trochanter of the femur, while the IP tendon audibly snaps as it moves, most commonly, over the pectineal eminence of the anterior pelvis [10].

✉ Wajeeh Bakhsh
wajeeh_bakhsh@urmc.rochester.edu

1 Department of Orthopaedics, University of Rochester Medical Center, 601 Elmwood Ave, Rochester, NY 14642, USA

2 Department of Radiology, University of Rochester Medical Center, Rochester, NY, USA

The IP tendon is more than just a source of hip snapping. It plays a significant role as a dynamic hip stabilizer [11]. The primary function of the IP muscle is hip flexion from 45 to 60 degrees of flexion. Secondarily, the tendon is a stabilizer of the femoral head within the acetabulum from 0 to 15 degrees of hip flexion [12]. When injured or inflamed, it can be a source of snapping and/or discomfort, and due to its anatomic relation to hip structures, tightness, or contracture can be symptomatic (Fig. 1). Chronic IP pathology, wear, or compromise can also contribute to atraumatic hip instability [13]. Therefore, IP involvement in snapping hip requires evaluation and potential intervention.

In evaluation of a snapping hip, distinguishing between intra- and extra-articular pathology is difficult. Advanced imaging is useful to evaluate for intra-articular causes [9]. Diagnosis of extra-articular pathology is often more challenging as it is clinical and reliant on physical exam. Between the two etiologies of extra-articular snapping hip, the IP tendon is more difficult to diagnose. IT band snapping is often reproducible at the lateral hip and can be easily palpated during hip range of motion [10]. Symptoms of IP pathology localize to the medial hip, as seen with intra-articular pathology [14]. However, IP tendon pathology has been shown to be more commonly associated with hip dysplasia versus other etiologies [2].

Both sources of extra-articular pathology are associated with coxa vara, or increased femoral head-neck angle, due to inefficiency of hip musculature [15]. IP pathology also demonstrates a relationship with anatomic variants, including the bifid IP tendon where the iliacus portion inserts inferior to the lesser trochanter (LT) of the femur while the psoas portion inserts at the LT [16]. A bifid IP tendon can result in snapping as the medial limb of the tendon flips over the lateral limb during hip flexion [17].

Imaging to diagnose the IP tendon as the etiology of a snapping hip can be useful. Dynamic ultrasound examination can demonstrate abrupt tendon movement that accompanies the audible snap on exam [18, 19]. However, as with all ultrasound, this is reliant on patient positioning, and can change based on symptom severity or patient compliance; therefore, it is not reliably reproducible. Correlation with other radiologic parameters can also yield valuable information. Lumbo-pelvic junction alignment has been thought to play a role in hip disorders in general, as it is significant for maintaining equilibrium of the dynamics between the hips and spine [20]. Pelvic incidence (PI), an angle between the hip joint and a line perpendicular to the sacral endplate, is a reliable measure of sagittal lumbo-pelvic alignment as it is position-independent [21]. PI has been shown to be associated with symptomatic hip pathology, as a decreased PI may play a role

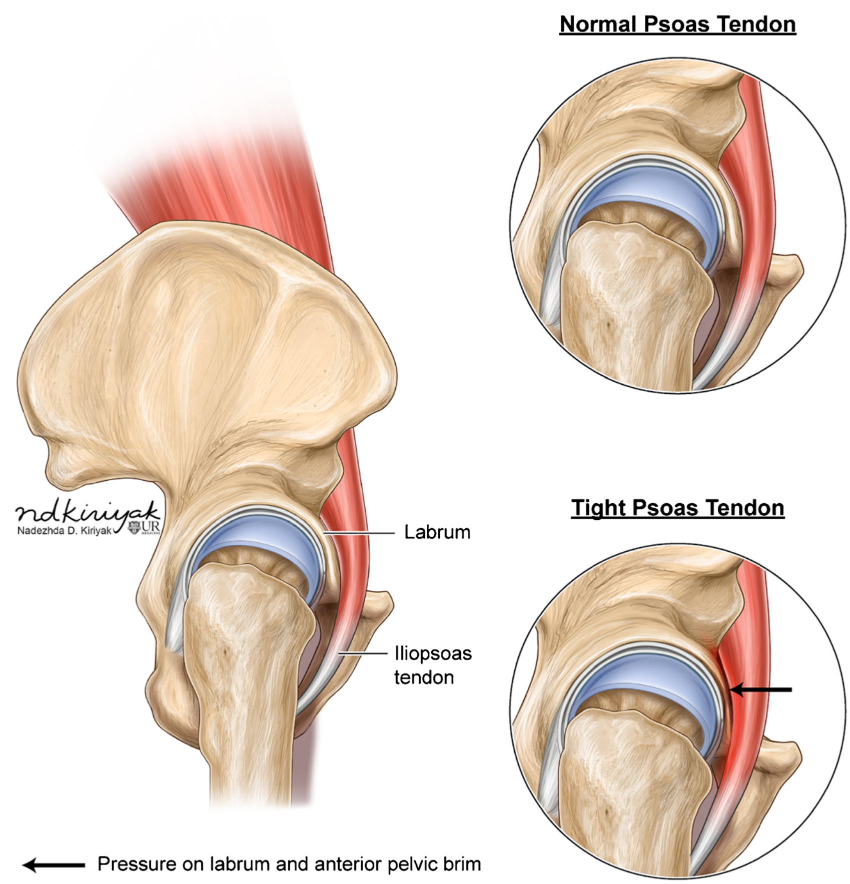

Fig. 1 Anatomic course of iliopsoas tendon. Figure depicting the course of the iliopsoas tendon with respect to the hip joint, highlighting anatomic relationships and associated problems with IP contracture

in femoro-acetabular impingement (FAI) [21, 22]. As a radiographic parameter, although thus far not associated directly with hip snapping, PI clearly influences hip mechanics and function and may potentially influence the clinical manifestations of an extra-articular hip pathology. Image-guided injections can also be used for diagnosis: when the IP tendon is injected with anesthetic under ultrasound guidance, symptomatic relief identifies the IP tendon as the etiology [23].

The use of magnetic resonance imaging (MRI) to diagnose IP tendon pathology as the cause of snapping hip has thus far been limited. MRI can show inflammation or signal changes in the IP tendon suspicious for tendon pathology, but with only a static image it has not been shown to reliably identify the tendon as the etiology [24]. There has been some diagnostic value previously documented with coronal MRI scans that trace the iliopsoas compartment, using the so-called "checkmark sign", which is similar to the coronal angle of the course of iliopsoas tendon [25]. However, we believe that the MRI can provide much more valuable information when reviewing certain radiologic parameters. Using minimum intensity projection, or MIP protocol, this study will explore patterns in radiologic measurements of the IP tendon along its course about the hip including the sagittal opening angle, pelvic incidence, and coronal angle. The goal is to compare these measurements between the groups and to identify what radiologic parameters, if any, can be used to identify patients that have an increased risk of IP tendon pathology and symptomatic snapping hip. The null hypothesis of the study is no difference between the groups with respect to MRI imaging parameters.

Methods

This IRB-approved study is a retrospective cohort study performed at a single surgical center by a single surgeon. Patients were identified by CPT billing code and ICD 9 or 10 diagnosis code for hip pathology. The control group included all patients with hip complaints warranting MRI of the hip but no clinical or radiologic findings consistent with hip snapping. These included diagnoses of hip pain, labral or chondral injury, femoral-acetabular impingement, loose bodies, and osseous or chondral defects. The IP hip snapping group included patients with a clinical or radiologic diagnosis of IP hip snapping without other concomitant hip pathology. All patients had been treated at a single surgical center between January 2015 and March 2016, with minimum 6-month follow-up.

Inclusion criteria includes patients age 18–80, treated by a single surgeon, with a hip MRI obtained to evaluate hip pathology. Exclusion criteria include age greater than 80, as tendon degeneration was thought to possibly affect imaging reliability. Other exclusion criteria include ipsilateral hip trauma, prior surgery to ipsilateral hip, or previous intervention for snapping hip. Patients with IT band pathology as the etiology of external snapping hip were excluded, as this study focuses on the IP tendon. Age 80+ were excluded due to age as a confounding variable. Patients with incomplete X-rays, MRI, or exams of insufficient quality were excluded as well. Demographic data was gathered through retrospective chart review of all enrolled subjects. This included age and gender.

Patients were separated into the IP hip snapping group if they had clinically documented IP tendon pathology as the etiology of an internal snapping hip. This was diagnosed with a combination of dynamic ultrasound examination, MRI tendinopathy, or signal change in the IP tendon in the absence of intra-articular hip pathology, and clinical exam. The remaining patients in the control group include all patients that obtained an MRI of the hip that met the above inclusion and exclusion criteria. This includes, largely, patients with intra-articular hip pathology, whether associated with hip snapping or not. Clinically, all patients were evaluated by a fellowship-trained, board-certified sports medicine orthopedic surgeon specializing in hip pathology.

MRI of the hip was reviewed for all subjects. All MRIs were obtained with the patient in supine position, with slight internal rotation of the hip. Minimum intensity projection (MIP) sequences were performed using a slab thickness of 15 mm concentrating on the iliopsoas tendon course in the coronal and sagittal planes [26, 27]. Minimum intensity projection is a rendering technique that detects the lowest signal voxels in a given volume and projects the data into a two-dimensional reformat. This method allows for improved visualization of the full extent of low signal intensity structures such as tendons. Three measurements were taken including pelvic incidence (PI), coronal angle (CA), and sagittal opening angle (SOA). PI was measured on sagittal radiographs of the lumbosacral spine and from the lateral scout view from CT scans of the hip as the sum of pelvic tilt and sacral slope (Fig. 2). The pelvic tilt is the acute angle measured on a sagittal image between a vertical line from the center of the femoral head and a line intersecting the midpoint of the S1 superior endplate. The sacral slope is the acute angle between a horizontal reference line and a line parallel to the S1 endplate [28]. CA was measured from the coronal MinIP reconstruction of the hip MRI. It is the measure of the angle of horizontal drift of the iliopsoas tendon relative to midline (Fig. 3). The angle is centered about the apex of the tendon's course around the femoral head, between a vertical reference line and a line along the distal path of the tendon. SOA was measured from the sagittal MinIP reconstruction of the hip MRI. The angle was centered at the apex of the iliopsoas tendons curvature in the sagittal plane and was determined by measuring the angle formed between a line tangent to the proximal portion of the tendon versus distal portion of the tendon relative to the apex of the curve. Example measurements can be seen in Figs. 4 and 5, with small and large SOA measurements, respectively. Measurements were performed by a single board-certified radiologist specializing in musculoskeletal imaging.

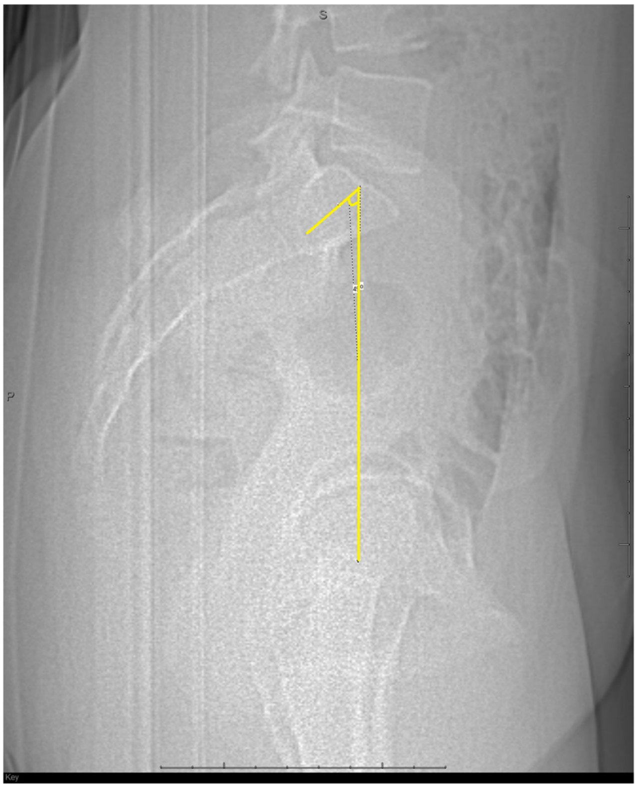

Fig. 2 Example of pelvic incidence

Subjects were then divided into groups with IP hip snapping pathology or the control group, as outlined above.

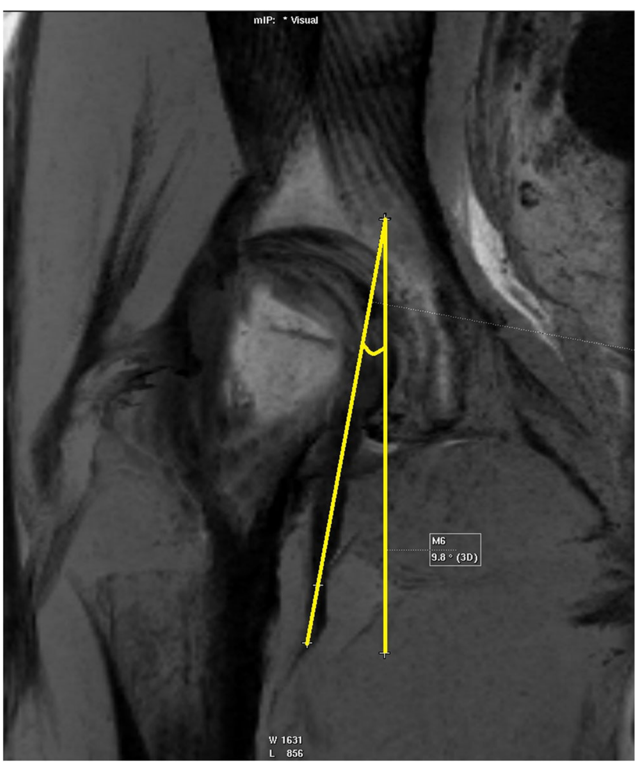

Fig. 3 Example of coronal angle

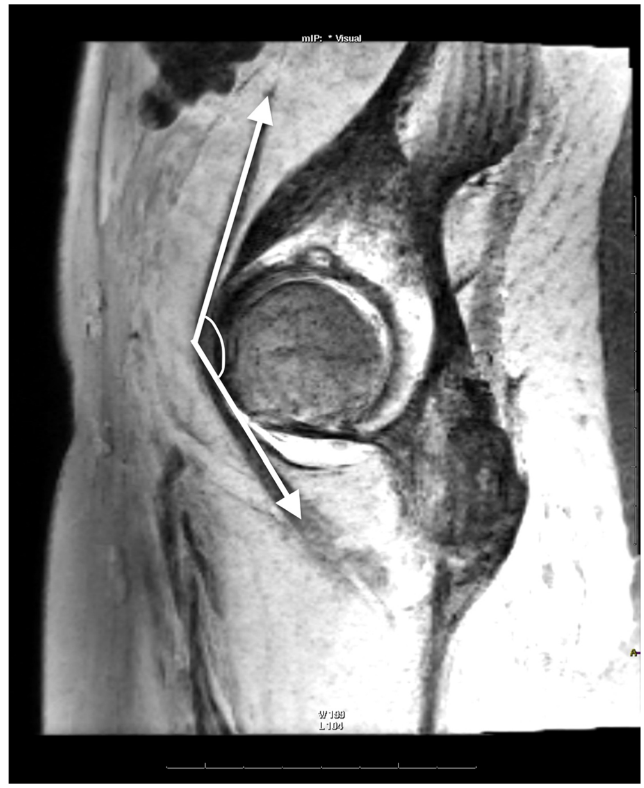

Fig. 4 Example of small sagittal opening angle. Example MRI projection using MIP of the course of an Iliopsoas tendon with a relatively small sagittal opening angle

Statistical analysis included basic summary analyses, non-parametric Mann–Whitney *U* test, frequency plotting, and receiver operating characteristic (ROC) analysis to identify any angle cutoffs that may provide correlations or potential diagnostic information.

Pre hoc power analysis was constructed to determine an effect size difference of 3 degrees in angle measurement, with a requirement of 46 subjects. Statistical significance was determined via a two-tailed distribution with cutoff of $p = 0.05$. Statistical analyses were performed via SPSS (IBM, Armonk, NY, USA).

Results

Of 172 patients that underwent MRI imaging within the associated timeframe, 85 were evaluated as the control group, with a mean age of 31.9 years. The IP hip snapping group included 48 patients, with a mean age of 31.7 years. Remaining patients were excluded for insufficient follow-up, incomplete or unusable imaging, or confounding injury; the distribution of excluded patients mirrored the 85 vs. 48 sample population. There was no significant difference in age or gender distribution between the two groups ($p = 0.32$, $p = 0.14$; Table 1).

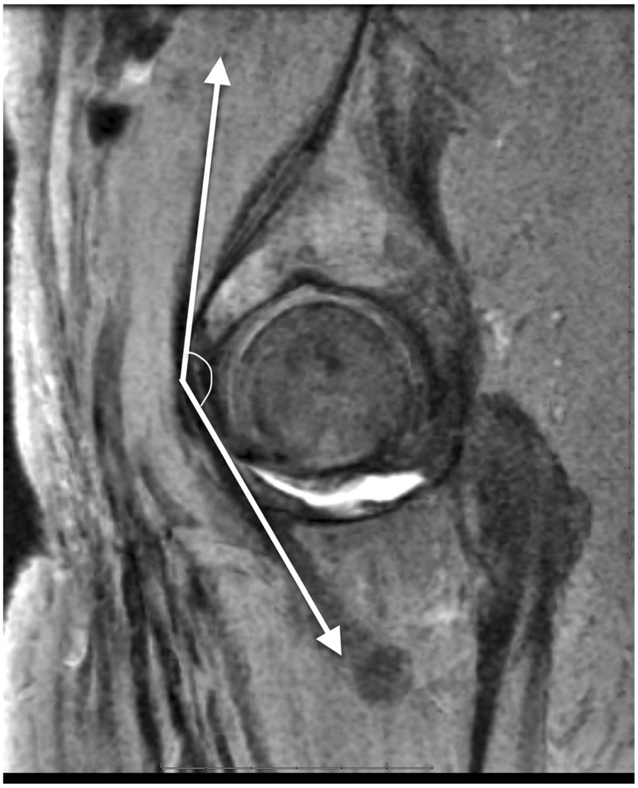

Fig. 5 Example of large sagittal opening angle. Example MRI projection using MIP of the course of an Iliopsoas tendon with a relatively large sagittal opening angle

Comparison of angles, documented in Table 2, demonstrates PI measurements with an average of 51.3 (± 10.7) degrees in the control group, and 52.2 (± 7.7) degrees in the IP hip snapping group. This difference was not significant ($p = 0.36$). Coronal angle measured a mean of 13.9 (± 4.6) degrees in the control group, versus 14.8 (± 4.8) degrees in the IP hip snapping group, with no significant difference ($p = 0.15$). SOA demonstrated an average of 137.0 (± 5.9) degrees in the control group versus 141.9 (± 6.5) degrees in the IP hip snapping group. This difference was statistically significant, with $p < 0.01$.

Specific analysis of the SOA was carried out with ROC analysis. Distribution of SOA measurements is demonstrated in Fig. 6. Distance to Corner methodology was used to identify the best cutoff SOA measurement, with 140 degrees providing the smallest distance to corner for the ROC plot (Fig. 7). Thirty-four of the 48 patients in the hip snapping group had SOA greater than 140 degrees, compared to 27 of 85 patients in the control group, which was a statistically significant difference ($p < 0.01$). The odds ratio (OR) for IP hip snapping given SOA > 140 degrees was 5.2 (2.4–11.3), making it significant (range does not include 1). The 140-degree SOA cutoff was 70.8% sensitive and 68.2% specific for IP hip snapping, with a positive predictive value (PPV) of 55.7% and negative predictive value (NPV) of 80.6% (Table 3).

Table 1 Demographic data comparison

	IP hip snapping	Control	*p* value
Age	31.7	31.9	0.32
Gender	13 M, 35 F	31 M, 54 F	0.14

Table 2 Radiologic parameter comparisons

	IP hip snapping: angle (standard deviation)	Control group: angle (standard deviation)	*p* value
Pelvic incidence	52.2 (7.7)	51.3 (10.7)	0.36
Coronal angle	14.8 (4.8)	13.9 (4.6)	0.15
Sagittal opening angle	141.9 (6.5)	137 (5.9)	< 0.01

Discussion

Hip snapping is a common musculoskeletal complaint, seen in 5–10% of the general population, and even more frequently in athletes [1]. While patients have demonstrated promising responses to both operative and non-operative treatment modalities, establishing the diagnosis can be complicated [7, 8]. Furthermore, symptomatic snapping of the iliopsoas often occurs as a spectrum of other disease states, such as FAI, atraumatic instability, acetabular dysplasia, or proximal femoral anteversion.

This condition presents a significant clinical challenge. Snapping symptoms can be aggravated with lumbo-pelvic hyperlordosis, whether a native anatomic variant or voluntary position in athletes such as dancers, as this brings the femoral head anteriorly in the acetabulum [29, 30]. Rehabilitation is therefore more involved than simply focusing on the IP tendon alone. Pelvic anteversion or proximal femoral anteversion can also result in increased biomechanical tension on hip flexor extrinsics, and can contribute to extra-articular hip snapping [31]. Therefore, symptomatic hip snapping is not necessarily a condition in isolation, but rather part of a constellation of pathology involving the hip, lumbar spine, and pelvis.

A significant challenge in workup of hip snapping syndrome is the identification of the exact etiology, as hip snapping is often a uniquely dynamic phenomenon and difficult to evaluate from static images. Dynamic ultrasound has been shown recently to aid in diagnosis of extra-articular etiologies, including both IT band and IP tendon pathology [18]. Until now, static MRI images have held limited value, as they can only demonstrate tendinopathy, which cannot be reliably used for etiological identification.

Previously, pelvic incidence has demonstrated a relationship with hip pathology, as a decreased PI is associated with

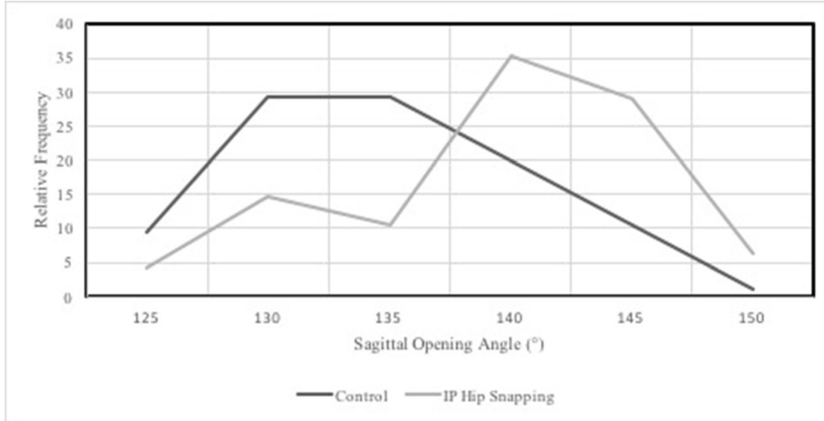

Fig. 6 Distribution of sagittal opening angle measurements displayed, demonstrating a significantly higher relative frequency with measurements of 140 degrees or greater in the IP hip snapping group

increased FAI [21, 22]. A decrease in PI is a relative restriction in spinopelvic motion, therefore limiting patients' ability to compensate for hip pathoanatomy. Recent studies have found a clear relationship between lower PI and cam and pincer deformities, suggesting that a lower PI results in increased stresses at the hip joint that result in bony overgrowth [22]. Therefore, it stands to reason that PI may play a role in IP hip snapping.

As hip snapping is involved with symptomatic FAI, this study prudently evaluated PI as a potential radiographic factor in patient presentation. CA and SOA measurements were evaluated as the MIP provided a unique static look at the course of the IP tendon about the hip, and both the CA and SOA serve as descriptors of said course. This study found no significant correlation between pelvic incidence or IP tendon coronal angle measurements and clinical hip snapping, which suggests that the previously established relationship between PI and the FAI syndrome may be related to pathology other than the IP tendon.

The significance of the sagittal opening angle findings suggests a relationship of increased SOA with IP tendon-associated hip snapping. Figure 6 demonstrates the distribution of SOA among the two groups. Since the SOA was significantly different between the groups, further analysis was carried out. While this study is not comprehensive enough to establish causation between SOA of the IP tendon and hip snapping, these findings reveal a correlation and potential diagnostic role of the SOA measurement. A greater SOA translates to a more vertically oriented course of the IP tendon. This likely implies a shorter IP tendon under greater tension, although this has not yet been studied and is an avenue for further potential biomechanical study. This could potentially explain why surgical procedures to lengthen the IP tendon are so effective in addressing hip snapping.

As the 140-degree SOA cutoff minimizes the distance to corner measurement of the ROC curve, it provides the greatest trade-off between sensitivity and specificity when evaluating for hip snapping in comparison to the control. With a sensitivity of 70.8% and specificity of 68.2%, an SOA measurement greater than 140 degrees is a fairly reliable marker for hip snapping pathology. As this is a limited retrospective cohort review, the SOA cannot be used independently as a diagnostic tool, but this correlation can aid diagnosis and guide treatment.

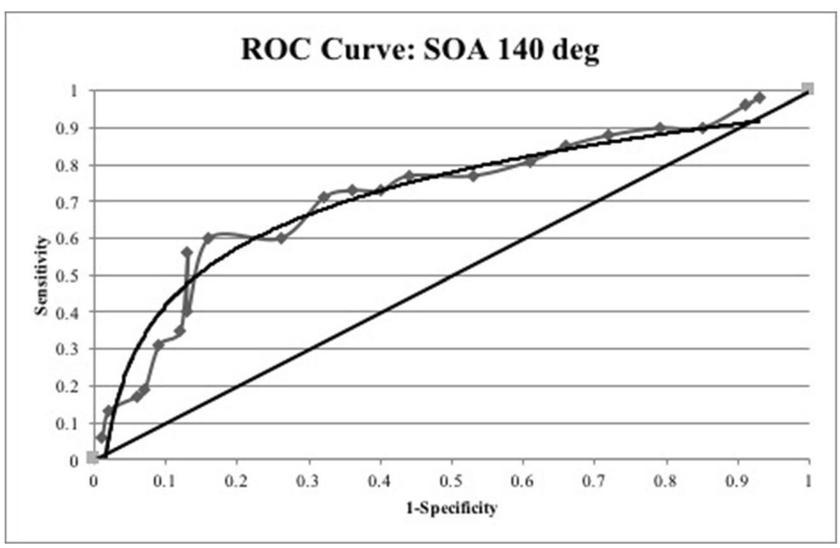

Fig. 7 ROC curve for sagittal opening angle > 140 degrees. Receiver operating characteristic curve for SOA threshold of 140 degrees demonstrates an excellent fit with area under the curve (AUC) of 71%

Table 3 Sagittal opening angle > 140 deg

Odds ratio (confidence interval)	5.2 (2.4, 11.3)
Sensitivity	70.8%
Specificity	68.2%
Positive predictive value	55.7%
Negative predictive value	80.6%

The SOA cutoff of 140 degrees has a NPV of 80.6%, which is a reliable degree of confidence and can aid in ruling out the IP tendon as a source of hip snapping pathology. With an odds ratio of 5.22, this data suggests patients with a SOA measurement of 140+ degrees are 5.22× more likely to have hip snapping complaints.

This study presents a unique imaging parameter, establishing confidence in the relationship between SOA of the IP tendon on MRI and hip snapping pathology. It has some value in identifying the etiology of internal hip snapping, which is thus far lacking in the literature. However, it is limited. As mentioned, this is a retrospective review, and the control group is not ideal as MRIs are not routinely obtained in asymptomatic patients without hip complaints. While the difference in angle measurements between the two groups was small, this study was sufficiently powered to detect such a difference. However, this study did not take into account the bifid anatomic variant of the IP tendon, and this could be a confounding variable. There is inherent bias in the study, as with its retrospective nature it does not fully capture patients with clinical IP hip snapping that did not undergo MRI. Additionally, only one radiologist well versed in SOA participated in obtaining angle measurements; the broad generalizability of this technique would benefit from more diverse participation in imaging assessment to ensure inter-observer reliability. Also, a matched case-control or prospective study may offer more robust findings, and offer an opportunity to avoid the aforementioned biases. Correlation of SOA with iliopsoas tendon signal change from a standard-projection MRI may offer additional insight. These findings could also benefit from a larger study on a broader population size, comparing radiologic parameters from hip snapping patients to those with no hip pathology. Outcomes data would be useful to identify if there are any trends amongst patients with imaging-associated IP hip snapping in regard to treatment modalities. Additionally, identification of further MRI imaging parameters to help with etiologic workup would be priceless in the workup of hip pathology.

Conclusions

Internal coxa saltans, or hip snapping, is a common orthopedic complaint. Diagnosis of a specific etiology can prove challenging, as the pathology is dynamic and complex biomechanical factors coexist and influence one another. While some newer diagnostic methods can help, this study establishes the value of the sagittal opening angle, a radiologic parameter found on MRI, and its relationship to hip snapping pathology of the iliopsoas tendon. This study most reliably demonstrates a negative predictive value of 80.6% with a SOA cutoff of 140 degrees, suggesting that a SOA below 140 degrees on MRI reliably correlates with the IP tendon not being involved in hip pathology. There is room for further study, but these findings help further the information that can be gleaned from a static image for this dynamic pathology.

Compliance with ethical standards

Conflict of interest None.

References

1. Piechota M, Maczuch J, Skupiński J, Kukawska-Sysio K, Wawrzynek W. Internal snapping hip syndrome in dynamic ultrasonography. J Ultrason. 2016;16(66):296–303.
2. Ilizaliturri VM Jr, Villalobos FE Jr, Chaidez PA, Valero FS, Aguilera JM. Internal snapping hip syndrome: treatment by endoscopic release of the iliopsoas tendon. Arthroscopy. 2005;21(11):1375–80.
3. Byrd JW. Snapping hip. Oper Tech Sports Med. 2005;13:46–54.
4. Winston P, Awan R, Cassidy JD, Bleakney RK. Clinical examination and ultrasound of self-reported snapping hip syndrome in elite ballet dancers. Am J Sports Med. 2007;35(1):118–26.
5. Flanum ME, Keene JS, Blankenbaker DG, Desmet AA. Arthroscopic treatment of the painful "internal" snapping hip: results of a new endoscopic technique and imaging protocol. Am J Sports Med. 2007;35(5):770–9.
6. Wettstein M, Jung J, Dienst M. Arthroscopic psoas tenotomy. Arthroscopy. 2006;22(8):907.
7. Dobbs MB, Gordon JE, Luhmann SJ, Szymanski DA, Schoenecker PL. Surgical correction of the snapping iliopsoas tendon in adolescents. J Bone Joint Surg Am. 2002;84(3):420–4.
8. Hoskins JS, Burd TA, Allen WC. Surgical correction of internal coxa saltans: a 20-year consecutive study. Am J Sports Med. 2004;32(4):998–1001.
9. Czerny C, Hofmann S, Neuhold A, et al. Lesions of the acetabular labrum: accuracy of MR imaging and MR arthrography in detection and staging. Radiology. 1996;200(1):225–30.
10. Lewis CL. Extra-articular snapping hip: a literature review. Sports Health. 2010;2(3):186–90.
11. Spiker AM, Degen RM, Camp CL, Coleman SH. Arthroscopic psoas management: techniques for psoas preservation and psoas tenotomy. Arthrosc Tech. 2016;5(6):e1487–92.
12. Yoshio M, Murakami G, Sato T, Sato S, Noriyasu S. The function of the psoas major muscle: passive kinetics and morphological studies using donated cadavers. J Orthop Sci. 2002;7:199–207.
13. Philippon MJ, Warth RJ, Briggs KK. Traumatic and atraumatic hip instability. In: Brockmeier S, editor. MRI-arthroscopy correlations. New York: Springer; 2015.
14. Mulroy RD. The iliopsoas muscle complex: iliacus muscle, psoas tendon release. Clin Orthop Relat Res. 1965;38:81–5.
15. Larsen E, Johansen J. Snapping hip. Acta Orthop Scand. 1986;57(2):168–70.

16. Polster JM, Elgabaly M, Lee H, Klika A, Drake R, Barsoum W. MRI and gross anatomy of the iliopsoas tendon complex. Skelet Radiol. 2008;37(1):55–8.
17. Deslandes M, Guillin R, Cardinal E, Hobden R, Bureau NJ. The snapping iliopsoas tendon: new mechanisms using dynamic sonography. AJR Am J Roentgenol. 2008;190(3):576–81.
18. Choi YS, Lee SM, Song BY, Paik SH, Yoon YK. Dynamic sonography of external snapping hip syndrome. J Ultrasound Med. 2002;21(7):753–8.
19. Pelsser V, Cardinal E, Hobden R, Aubin B, Lafortune M. Extraarticular snapping hip: sonographic findings. AJR Am J Roentgenol. 2001;176(1):67–73.
20. Lazennec J-Y, Brusson A, Rousseau M-A. Hip-spine relations and sagittal balance clinical consequences. Eur Spine J. 2011;20:686–98.
21. Weinberg DS, Gebhart JJ, Liu RW, Salata MJ. Radiographic signs of femoroacetabular impingement are associated with decreased pelvic incidence. Arthroscopy. 2016;32(5):806–13.
22. Hellman MD, Haughom BD, Brown NM, Fillingham YA, Philippon MJ, Nho SJ. Femoroacetabular impingement and pelvic incidence: radiographic comparison to an asymptomatic control. Arthroscopy. 2017;33(3):545–50.
23. Blankenbaker DG, De Smet AA, Keene JS. Sonography of the iliopsoas tendon and injection of the iliopsoas bursa for diagnosis and management of the painful snapping hip. Skelet Radiol. 2006;35(8):565–71.
24. Wahl CJ, Warren RF, Adler RS, Hannafin JA, Hansen B. Internal coxa saltans (snapping hip) as a result of overtraining: a report of 3 cases in professional athletes with a review of causes and the role of ultrasound in early diagnosis and management. Am J Sports Med. 2004;32(5):1302–9.
25. Eshed I, Inbar Y, Hertz M, Apter S. Checkmark: a sign for the detection of iliopsoas pathology on MRI of the hip. Acta Radiol. 2010;51(5):539–42.
26. Caramella D, Neri E. Advanced image processing. In: Bartolozzi C, Lencioni R, editors. Liver malignancies. Medical Radiology (Diagnostic Imaging and Radiation Oncology). Berlin: Springer; 1999.
27. Tongdee R, Narra VR, Oliveira EP, Chapman W, Elsayes KM, Brown JJ. Utility of 3D magnetic resonance imaging in preoperative evaluation of hepatobiliary diseases. HPB (Oxford). 2006;8(4): 311–7.
28. Saltychev M, Pernaa K, Seppänen M, Mäkelä K, Laimi K. Pelvic incidence and hip disorders. Acta Orthop. 2018;89(1):66–70.
29. Jacobson T, Allen WC. Surgical correction of the snapping iliopsoas tendon. Am J Sports Med. 1990;18:470–4.
30. Laible C, Swanson D, Garofolo G, Rose DJ. Iliopsoas syndrome in dancers. Orthop J Sports Med. 2013;1(3):2325967113500638.
31. Spina AA. External coxa saltans (snapping hip) treated with active release techniques: a case report. J Can Chiropr Assoc. 2007;51(1): 23–9.