Screening active patients with new onset hip pain for femoroacetabular impingement

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Dedication

Thank you to all of my classmates in the University of Toledo Physician Assistant Program, class of 2012. It was great to share thoughts (and complaints) about the project with you, and to have others who understood the frustrations I occasionally felt.

A thank you also goes out to my wife for her patience in my writing of this paper, as well as putting up with my frustrations! Time together was lost, but it was all for a higher goal. .

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Table of Contents

Introduction

Hip pain is a very common orthopedic symptom, with 7% of all adults and almost 15% those over sixty years of age being affected (Centers for Disease Control and Prevention, 2006; Christmas et al., 2008). While hip pain is often associated with osteoarthritis (OA), multiple other causes must be included in the differential diagnosis. These include other forms of arthritis (i.e. gout, rheumatoid arthritis, etc.), hip adductor and flexor muscle strains, greater trochanteric bursitis, sacroiliitis, labral tears and the relatively new diagnosis of femoroacetabular impingement (FAI). While hip pain is generally viewed as a complaint of the geriatric population, the incidence is rising in the younger, active population (Imam & Khanduja, 2011). This is especially apparent in those who are very active in athletics, particularly hockey and soccer athletes, as well as participants in other activities requiring significant hip flexion and internal rotation.

Case: Mr. H is a 27-year-old male who presents to the family practice office with hip and groin pain that began six weeks ago. He first noticed the pain about twenty-four hours after playing in a softball game, though he does not recall a specific precipitating injury. Since that time, he has noticed a sharp pain in the anterior right thigh and groin when he runs on a treadmill or participates in softball. Occasionally, when he feels the sharp pain he also notes a deep "clicking" sensation in the affected hip. For the past week, he has also noticed that the pain occurs after he sits for more than an hour at his desk during his job as an accountant. Mr. H is otherwise healthy without significant past medical history or surgical history. He lives a very active lifestyle, exercising to stay fit and participating in organized sports leagues, with hockey in the winter and slow pitch softball in the spring and summer.

Primary care clinicians who are evaluating young and active individuals with hip pain, such as Mr. H, need to consider FAI as a possible diagnosis. FAI has been defined as damage to the chondrolabral tissue resulting from abnormal bony contact between the femoral head and acetabulum, which is resultant from asphericity of the femoral head and/or overcoverage of the femoral head by the acetabulum (Imam & Khanduja, 2011; Kassarjian, Brisson, & Palmer, 2007; MacFarlane & Haddad, 2010). Congenital etiologies of FAI include Legg-Calves Perthes disease (LCP), congenital hip dysplasia, and slipped capital femoral epiphysis (SCFE); however, the most common cause appears to be repetitive hip motion, especially excessive hip flexion and rotation (Beall et al., 2005). Over time, the impingement occurring between the femoral head and the acetabulum with FAI causes bony changes potentially leading to labral tears and premature OA (Ganz et al., 2003). While precise incidence and prevalence rates related to FAI are lacking, the literature suggests that these rates in the overall adult population are increasing, with the sharpest spike in the young adult category (Domayer et al., 2010; Imam & Khanduja, 2011).

There are three types of FAI. The first, cam-type FAI, is consistent with an exostosis of the femoral head, most commonly on the anterosuperior surface (Clohisy, Nunley, Otto, & Schoenecker, 2006). This type is termed “cam” because the mechanics of the hip with this disorder resembles the rotating mechanism that converts rotary motion into linear motion in machinery. The lesion causes a deficient offset between the femoral head and neck (MacFarlane & Haddad, 2010). This type of FAI most commonly occurs in younger males (Anderson, Siebenrock, Mamisch, & Tannast, 2009; Brian, Bernard, & Flemming, 2010) and formation of this lesion is believed to be multifactorial. Well-described congenital conditions such as LCP, SCFE, and retrotorsion of the femoral head can lead to the formation of a cam lesion (Brian et al., 2010). More commonly, however, patients present with the bony growth idiopathically (Brian et al., 2010). The sequelae of this deformity include shearing forces leading to labral tears, delamination of the articular cartilage from the acetabulum, and an increased risk of premature OA (Barton, Salineros, Rakhra, & Beaule, 2011; Brian et al., 2010; Macfarlane & Haddad, 2010).

Secondly, pincer-type FAI occurs due to bony overgrowth of the acetabulum, resulting in overcoverage of the femoral head (Barton et al., 2011; Imam & Khanduja, 2011; MacFarlane & Haddad, 2010). This overcoverage can also occur due to acetabular retroversion, coxa profunda, or acetabular protrusion (Barton et al., 2011). In addition to the FAI symptoms, the acetabular labrum can be damaged from repetitive excessive bony contact between the femoral head and acetabulum. Natural healing mechanisms often lead to the damaged labrum scarring back to the underlying acetabulum. When this occurs chronically, the healing labrum ossifies, creating a larger acetabular rim, and thus further overcoverage of the femoral head (Rylander, Froelich, Novicoff, & Saleh, 2010). The symptomatic patient with pincer-type FAI is commonly a middle-aged, active female (Brian et al., 2010). This deformity can lead to labral and posterior hyaline cartilage damage (Brian et al., 2010).

The third type of FAI, termed mixed-type, is actually a combination of the cam and pincer types, and should be considered the “rule” as opposed to the “exception” (Rylander et al., 2010; Hong et al., 2008). With this type of FAI, patients have both an aspherical femoral head and acetabular retroversion (Hong et al., 2008). Patients presenting with mixed FAI most often report an insidious onset of groin pain that initially tends to occur with athletic activity, but as the disease progresses, simply sitting in one position for prolonged periods becomes painful (Rylander et al., 2010). Hong et al. (2008) theorized that the osteophyte observed in the cam deformity was caused by premature OA, and the same theory may hold true with the acetabular rim osteophyte. As with cam and pincer-type FAI, sequelae of mixed-type FAI includes shearing of the labral-chondral transition zone. This can then lead to further damage to the adjacent articular cartilage, and predispose the patient to premature OA (Hong et al., 2008).

While premature OA is a concern for long-term FAI, damage to the acetabular labrum is a more acute and common complication of the condition. The key to minimizing the complications of labral tear and subsequent premature OA is early identification and treatment of FAI. The acetabular labrum is a fibrocartilage ring that acts to increase the amount of contact between the femoral head and acetabulum. Articular cartilage attaches to the labrum anteriorly and posteriorly, though in different fashions. Anteriorly, the chondrolabral junction is sharp with only a marginal transition zone (Rylander et al., 2010). This is in contrast to the posterior rim where there is a much larger transition zone (Rylander et al., 2010). This difference in transition zones may explain why the tendency of labral tears associated with FAI, particularly cam-type FAI, occur anteriorly. It is believed that flexion and internal rotation with an osseous deformity on the femoral head-neck junction (cam-type FAI) causes increased contact with the acetabulum, leading to shearing stress and delamination of the anterior articular cartilage (Rylander et al., 2010). Due to the small transition zone, this delamination quickly progresses to produce labral pathology, causing a labral tear that is displaced superiorly (Rylander et al., 2010). Although this type of labral tear is the least-complicated to treat surgically, the fact that delamination of the articular cartilage has occurred and is irreversible marks the beginning of premature OA (Rylander et al., 2010).

With pincer-type FAI, the labral pathology occurs before delamination of the articular cartilage as a result of the large chondrolabral transition zone. Acetabular overcoverage of the femoral neck results in femoral neck contact with the acetabulum during normal range of motion. This, in essence, “crushes” the labrum and may be associated with paralabral cysts (Rylander et al., 2010).

Patients with any of the three types of FAI often present with similar complaints. Mr. H represents the typical patient that the family practice PA will encounter. Deep, sub-acute or chronic groin pain with increasing severity during activity that remains symptomatic at rest is a classic presentation of FAI (Beall et al., 2005; Imam & Khanduja, 2011; MacFarlane & Haddad, 2010). Further reports of clicking or catching in the joint by the patient warrant follow-up and testing to rule-out acetabular labral injury.

When a patient such as Mr. H presents to the office, a thorough physical exam should be performed. The patient’s gait should be examined for signs of abnormality, such as an antalgic or Trendelenberg gait, to examine for possible functional causes of the patient’s hip pain. The alignment of the hip should also be assessed by examining the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), and any leg length discrepancy, as bony malalignments can be cause for the patient’s hip pain. The hip musculature should be examined to determine if there is any atrophy and palpated for tenderness. Other structures that should be palpated include the greater trochanter, ASIS, PSIS, and iliotibial band. The patient’s range of motion should also be assessed, including active, passive, and resistive motions in all planes. When a patient like Mr. H presents with groin pain, it is particularly important to assess hip internal rotation with the hip flexed to 90 degrees. Less than 15 degrees of internal rotation in this position is pathologic and highly suspicious for FAI (Beall et al., 2005). Additionally, the impingement test should be performed. To perform the impingement test, the practitioner passively flexes the patient’s hip. Once at full passive flexion, the examiner places the hip into internal rotation by internally rotating the tibia, and passively adducts the hip towards the midline. The hip is then passively extended. Passive hip flexion is repeated, and the hip is placed into external rotation by externally rotating the tibia. The hip is then passively abducted away from the midline and passively extended. The presence of increased pain and/or clicking/catching with flexion, adduction, and internal rotation of the affected hip is suspicious for a cam lesion (Beall et al., 2005). The hip scour test may also be performed as further indication of intraarticular damage. Additionally, the FABERE and sacroiliac compression/distraction tests should be performed to rule out pathology of the sacroiliac joint; the Thomas test should be performed to assess if rectus femoris tightness is the underlying pathology; and the Ober test should be performed to assess for iliotibial band pathology.

Following the history and physical examination, if the family practice PA suspects that a patient such as Mr. H has FAI, diagnostic imaging is the appropriate next step. In many family practice settings, patients with hip pain are referred for radiograph imaging, which includes AP pelvis and lateral view radiographs. These images may be sufficient to detect many types of hip pathologies, such as advanced OA, LCP or SCFE. Regarding FAI, pincer deformities, can be recognized by a trained clinician and should be noted by the radiologist (Barton et al., 2011). However, in young adult patients with atraumatic hip pain, such as Mr. H, the initial films are often interpreted as inconclusive as they are not sufficient to evaluate many disorders, including most cases of FAI. In these instances, the family practice PA has a few options: use a presumptive diagnosis of groin or hip strain or sprain and treat accordingly, or pursue more advanced imaging. Appropriate treatment for a sprain/strain include stopping all activities that produce the pain; using nonsteroidal anti-inflammatory drugs, ice and/or heat for symptomatic treatment; and physical therapy.

Using the presumptive diagnosis of a groin strain, Mr. H receives analgesics, is instructed to limit the offending activities, and is referred for physical therapy. At the six week follow-up appointment, Mr. H reports a decrease in symptom severity, but still complains of a dull ache in his groin. He attempted to return to more rigorous activities, but the pain quickly returned. At this time, the general practice PA must either refer Mr. H to an orthopedic specialist and/or pursue advanced imaging. Understanding the high likelihood that this is cam-type FAI, the PA decides to pursue advanced imaging; however, the literature suggests that while many imaging modalities are available, the evidence-based best choice is unknown. The use of many imaging modalities has been proposed, including radiographs using specific views, MRI, computed tomography (CT), three-dimensional computed tomography (3D-CT), ultrasound (US), and bone scintigraphy.

Early detection of FAI is imperative to prevent further damage to the femoroacetabular joint. Pincer-type FAI is usually detected with standard radiographs; however, there is debate as to which modality should be used to image cam-type FAI. The goal of this review is to identify which imaging modality should be ordered in the young adult patient with atraumatic hip pain suggestive of cam-type FAI.

Methods

In March, 2012, PubMed was utilized using the advanced search option. The search terms used were “femoroacetabular impingement”, “cam-type impingement”, and “cam impingement”. Builders were utilized to combine all three terms into one comprehensive search using the “or” and “title” options. In September, 2012, this process was repeated and the search revealed 311 possible articles for review.

Articles were evaluated based on set inclusion and exclusion criteria. Inclusion criteria included: publication in English in a peer-reviewed journal; publication date within the past 10 years; the entire study population were live humans; the mean age of the studied population was less than 65 years old; the patient population had symptomatic, atraumatic hip pain; and the article made a recommendation to use a particular modality to diagnose FAI. Exclusion criteria included: any study that was performed using cadavers; greater than 5% of the study population had prior hip surgery; any member of the study population had congenital or adolescent-diagnosed hip abnormalities (LCP, SCFE, etc); the study population included participants with a previous fracture of the femoral head, neck, or head-neck junction; the article was treatment-based; or the sequelae of FAI was the central theme. A total of 11 articles were found to meet these criteria and were analyzed.

Literature Review

Radiographs have long been the first line imaging modality for virtually all patients with hip pain and are also often used initially in patients where FAI is suspected. Diagnostic imaging for cam-type FAI with regard to patient positioning and diagnostic measurements has been the topic of multiple research studies. Clohisy et al. (2006) were the first to suggest radiographic views that differed from the standard AP and lateral views. In their retrospective review, the authors examined the radiographs of 56 patients with groin pain, a positive impingement test, and radiographic evidence of femoral head asphericity and/or a reduced femoral waist. These patients were then compared to an asymptomatic control group matched for age and gender. The radiograph series included an AP, cross-table lateral (CTL) and frog-leg (FL) views. For each image, the alpha angle, femoral head sphericity, and head-neck offset were determined, and the interobserver reliability was calculated. Results showed that the FL view had a mean alpha angle measurement of 43.7 degrees for the control group and 65.2 degrees for the study group, with $p<.001$. Of the three projections, the FL view produced the greatest alpha angle, as well as the greatest difference in alpha angle measurements between the symptomatic and asymptomatic groups. Furthermore, the FL view produced statistically significant results in identifying an aspheric femoral head and determining femoral head-neck offset, with $p<.001$ for each. The results of analyzing the FL view also demonstrated very high reliability in measuring head sphericity and the alpha angle, with interobserver agreements of 0.82 and 0.83, respectively. From these findings, the authors concluded that the alpha angle is the most useful measurement in detecting an aspheric femoral head, with the FL view as the most reliable view to take this measurement. The authors also determined that because the FL had the largest difference between the control and study groups, it identifies cam FAI deformities most readily.

Following the study from Clohisy et al, which was largely based on the alpha angle measurement, Gosvig, Jacobsen, Palm, Sonne-Holm, and Magnusson (2007) published their study results on a new radiologic index for assessing femoral head sphericity. In this retrospective study that was a subset of the Copenhagen heart study, the AP pelvis radiographs of 2,803 subjects were examined. Included in this group were 164 patients who later had a total hip replacement. For each radiograph, the alpha angle was determined, as was the new measurement, termed the triangular index (see appendix A). The reliability of the triangular index was then compared to the alpha angle measurements. The researchers found that the mean alpha angle in men was 52.4 degrees ($p<.001$) and 45.9 degrees in women ($p<.001$), both of which are below the threshold for diagnosing FAI. The triangular index was closely related with the alpha angle in diagnosing cam deformity, with $p<.001$ in men and $p=.001$ in women. In the 164 hips scheduled for surgery, 42% were found to have a cam deformity intraoperatively. Of this 42%, 97% were detected on the AP radiograph when measuring both the alpha angle and triangular index. From this, the authors concluded that cam deformity is detectable to an acceptable level on standardized AP pelvic radiographs when excessive rotation (i.e. lateral views) of the pelvis and hip are avoided, especially when using the triangular index. Furthermore, they concluded that because the alpha angle can be underestimated in AP radiographs, concurrent assessment of the triangular index increases both inter and intraobserver reliability.

Following the idea of Gosvig et al., Brunner, Hamers, Fitze, and Herzog (2010) developed another radiologic index to assess femoral head sphericity, thus challenging the notion that the alpha angle was the ideal measurement for determining head asphericity. In their clinical study, Brunner et al. compared 50 patients with symptomatic FAI evidenced by a positive impingement test against a control group of 50 asymptomatic patients. AP pelvis radiographs were taken of each of the participants, and for each subject the beta angle was measured (see appendix). Additionally, MRA images were taken of each patient and the alpha angle was determined. All participants in the symptomatic group had an alpha angle greater than 55 degrees on MRA, while all participants in the control group had an alpha angle measurement less than 55 degrees. The inter and intraobserver reliabilities of the beta angle measurement were also determined. The results showed that the symptomatic group had a significantly smaller mean beta angle than the control group, with a mean beta measurement of 15.6 degrees versus 38.7 degrees, respectively (p<.01). The beta angle also produced very high inter and intraobserver reliabilities, with mean values of 0.82 and 0.89 respectively for the study group, and 0.89 and 0.85 for the control group. From these results, the authors concluded that the beta angle can be easily measured and has sufficient reproducibility for use in daily practice. Furthermore, they concluded, small beta angle measurements on AP radiographs in symptomatic patients may alone be sufficient to make the diagnosis of cam-type FAI.

In a study that made some clinicians question the validity of the FL measurement, Konan, Rayan, and Haddad (2010) retrospectively compared femoral head sphericity and the alpha angle measurement on FL radiographs in 32 symptomatic patients against CT images taken from the same population. The authors assessed femoral head sphericity via a best-fit circle on a FL radiograph. If a prominence was seen outside this best-fit circle, the femoral head was determined to be aspherical. Additionally, the authors measured the alpha angle on the FL view and compared the measurement against the alpha angle determined on CT images, which was used as the standard of reference. Femoral head sphericity measured on the FL view had a reliability of 0.57, considered moderate by the authors’ definition. The mean alpha angle on the

FL radiograph was 58.71 degrees, as opposed to 65.11 degrees measured on CT, resulting in an interobserver reliability of 0.83, and an intraobserver reliability of 0.88. Though there was high reliability, the interclass coefficient between the FL radiograph and CT was only .08, which was considered poor. Based on these results, the authors concluded that although plain radiography is cost effective, many factors influence its accuracy, and therefore imaging by CT is essential for high sensitivity in screening patients for a cam lesion.

While Konan et al. questioned the use of radiographs to diagnose FAI, Barton et al. (2010) published a study that demonstrated its effectiveness, and validated use of the alpha angle as a diagnostic measurement. In a retrospective study of 68 patients, 43 with known cam deformity, Barton et al. compared the reliability of alpha angle measurements of AP, cross-table lateral, and Dunn view radiographs against the alpha angle measured on an oblique axial MRA image. The authors found a mean alpha angle of 59 degrees on the MRA images, 61 degrees on the Dunn view ($p<.001$), 63 degrees on the cross-table lateral view ($p<.001$), and 65 degrees on the AP view ($p<.05$). When comparing the various radiographic views to the MRA views, the Dunn radiographic view demonstrated nearly identical diagnostic measurements, with Pearson correlation coefficients of 0.91 for sensitivity, 0.88 for specificity, 0.93 for positive predictive value (PPV), 0.84 for negative predictive value (NPV), and 0.90 for accuracy. The Dunn view also had exceptional reliability, with inter and intraobserver reliabilities of 0.90 and 0.979, respectively. The AP and cross-table radiographic views also had strong statistical evidence for their use, though not as strong as the Dunn view. From this, the authors concluded that the Dunn view is highly representative of MRI measurements in terms of the alpha angle measurement; radiographs in the Dunn position with measurement of the alpha angle may alone be adequate for the diagnosis of FAI; and alpha angle measurements on plain radiographs are accurate compared to the gold standard MRA.

While Barton et al. used the oblique axial MRI plane as the standard of reference for comparison of radiographs, Domayer et al. (2010) used a different MRI plane recommended by Rakhra, Sheikh, Allen, and Beaule (2008) that was found to be superior in visualizing the anterosuperior quadrant of the femoral head (the most common site of cam lesions). In a retrospective study of 60 symptomatic hips, alpha angles in AP, Dunn, and CTL radiographs were compared to the alpha angle measurement determined in the radial MRI plane. This plane was chosen because research by previous authors found that it produced the largest alpha angle measurement in the anterosuperior quadrant of the femoral head (Rakhra et al., 2008). Using an alpha angle measurement greater than or equal to 55 degrees as the diagnostic cutoff for a cam deformity, the radial MRI images diagnosed cam deformity in 45 of the 60 patients, and this value was used as the standard of reference. Images in the AP radiographs diagnosed 26 of the 60 patients with a cam deformity, and images taken in either the CTL or Dunn views diagnosed 35 of the 60 patients with a cam deformity. When the AP view plus was read concurrently with either a Dunn or cross-table lateral view, 40 of the 45 MRI-positive patients were correctly diagnosed with a cam deformity. Additionally, it was found that the Dunn view had the overall best radiographic sensitivity and specificity percentages, with 96.4% and 90%, respectively. These findings led Domayer et al. to conclude that the Dunn radiograph view provides excellent sensitivity and is a reliable radiographic view to use. The success of the Dunn view, they explained, was due to its ability to aim the camera where the maximum cam deformity is found in the majority of FAI cases. However, they further concluded that MRI alone is more sensitive than radiographs, even when multiple views are read concurrently, and therefore MRI remains indispensable for the evaluation of symptomatic patients.

With its low cost and wide availability, radiographs have been extensively studied for the diagnosis of FAI. Though there has been less published literature about its use, CT has been recommended as a first-line modality by multiple authors. As previously mentioned, Konan et al. preferred CT over the FL radiographic view, and similar suggestions have been published by other authors. In 2005, Beaule, Zaragoza, Motamedi, Copelan, and Dorey presented the use of 3D-CT in diagnosing cam-type FAI. In their study, the authors examined the hips in 36 patients who presented with 3 months of persistent hip pain, a positive impingement test, and minimal response to conservative treatment. Each subject had an AP and FL radiograph taken of the symptomatic hip to ensure normal anatomy of the acetabulum. MRA imaging was also taken to assess for chondrolabral damage. Following this, the participants had the symptomatic hip scanned with a high-speed CT that recreated two-dimensional and three-dimensional images. The alpha angle and alpha/beta ratio were each determined on the three-dimensional image. These results were then compared to the results of an asymptomatic control group of 12 subjects who were subjected to the same imaging. The authors found a mean alpha angle of 66.4 degrees in the symptomatic group versus 43.8 degrees in the control group ($p<.001$). The mean alpha/beta ratio was 1.68 in the study group versus 1.01 in the asymptomatic group ($p=.001$). Based on the 3D reconstructions, 29 of the 36 symptomatic participants had a cam deformity as determined by the alpha/beta ratio, while 26 of the 36 subjects were positive for cam deformity based on the alpha angle. Overall, 3D-CT had moderate inter and intraobserver reliability (0.6 and 0.67, respectively). This led Barton et al. to conclude that 3D-CT is an accurate tool to assess abnormalities of the femoral head-neck junction with moderate reliability. Furthermore, they concluded, 3D-CT provides virtual reality quantification of the deformity size for both patients and surgeons.

Expanding on the research by Barton et al., Tannast et al. (2006) examined the use of 3D-CT in diagnosing FAI through virtual range of motion measurements. This study centered on information obtained through the HipMotion™ CT imaging system. Thirty-six asymptomatic patients with anatomically normal hips were included in the control group, and 31 symptomatic hips with radiographic evidence of FAI were in the study group. Flexion, extension, internal and external rotation at 90 degrees of hip flexion, abduction, and adduction ranges of motion were determined in each group based on 3D reconstruction of CT images obtained with the HipMotion™ software. The authors found statistically significant differences in flexion ($p<.001$), internal rotation at 90 degrees of hip flexion ($p<.001$), and abduction ($p<.001$) when comparing the two groups, with the asymptomatic group having greater range of motion for each. When examining reliability, there was near perfect correlation coefficients for all the range of motion measurements except external rotation at 90 degrees of hip flexion. This information led the authors to conclude that 3D-CT can provide virtual reality representation of the anatomy of the hip, thus quantifying pathologic anatomy. Therefore, they concluded, this modality provides a reliable, accurate, and noninvasive tool for the assessment and treatment of hip impingement caused by FAI. The authors also concluded that typically, the diagnosis and treatment of FAI is based on two-dimensional assessment; however, confirmation of this is difficult to achieve even if radial MRI is used.

The use of CT, and in particular 3D-CT, for the diagnosis of FAI has been discussed by multiple authors. One set of authors advocated for use of a modality to detect FAI before the patient experienced significant symptoms. Matar, May, Raymond, and Beaule (2008) conducted a study on 25 symptomatic patients using single-photon emission computed tomography (SPECT), also known as bone scintigraphy or bone scan. Participants were determined to have FAI if they reported pain in a particular hip, had a positive impingement sign, and had radiographic evidence of FAI. Of the 50 hips examined, 26 were included in the symptomatic group, and 24 that did not meet all three diagnostic criteria were included in the control group. Following placement, each hip was studied by bone scan, and the authors examined for increased uptake in the acetabulum and femoral head-neck junction. They found that of the 26 FAI-positive hips, 22 had uptake on the bone scan. Additionally, 9 of the 24 hips in the control group had positive uptake, identifying these patients as being false-negatives at the onset of the study. SPECT was found to have a sensitivity of 84.7%, specificity of 62.5%, PPV of 71%, and NPV of 78.9%. With SPECT identifying nine false-negatives, the authors concluded that a positive SPECT can be an early indicator of intraarticular cartilage damage that presents before symptoms of FAI manifest, and if there is intraarticular cartilage damage, a cam deformity is likely. They also concluded that bone scintigraphy represents a relatively sensitive test to confirm intraarticular hip abnormalities when FAI is clinically and radiologically suspected.

All of the studies presented so far incurred a significant radiation burden on the patient. Buck, Hodler, Zanetti, Dora, and Pfirrmann (2010) presented a method for FAI detection that did not incur a radiation burden. In their landmark study, they examined 50 patients with a history of groin pain and impaired flexion and internal rotation using ultrasonography (US). Using US, the authors determined the alpha angle and assessed for other anatomic abnormalities of the femoral head and neck. Following this, the patients underwent MRA and had radial reformations created to measure the alpha angle. Using the MRA-determined alpha angle as the standard of reference, US demonstrated a mean agreement of 57% at the anterior femoral head, and 60% at the anterosuperior femoral head. Comparable data was found for specificity, NPV, PPV, and accuracy. US did, however, demonstrate high sensitivity measurements, with a mean sensitivity of 91.5% compared to the radial MRA. The authors concluded that due to US being fast and inexpensive, with high availability and no radiation exposure, it can be used as a first-line modality to determine if radiograph or MRI follow up is necessary, as the presence of an anterosuperior cam deformity is a sensitive finding.

MRI has commonly been used as the standard of reference for comparison of data from other imaging modalities, particularly in measurement of the alpha angle. Since it was first studied, the alpha angle has been used as the preferred objective measurement to diagnose cam deformities. Much like radiographs, there has been discussion on which MRI view produces the most reliable data. Rakhra et al. (2008) compared the alpha angle measurements on oblique axial and radial MRI images in 41 subjects who had a high clinical suspicion for FAI and abnormal radiographic findings suggestive of FAI. Using the oblique axial plane, the mean alpha angle was 53.4 degrees, which is below the common cutoff of 55 degrees used to diagnose a cam deformity. In the radial plane, the average alpha angle was 70.5 degrees, with $p<.001$. The large difference was explained as being due to the positioning of cam deformities. Visualizing the femoral head as a clock face, the authors found that the maximum alpha angle measurement occurred at the 2 o’clock position (the anterosuperior quadrant). The oblique axial view did not have the capability to visualize this portion of the femoral head, and thus produced a significantly lower mean alpha angle. From this, the authors concluded that the oblique axial MRI evaluates the anterior femoral head well, but underestimates the anterosuperior portion where the majority of cam deformities occur. Rather than using oblique axial MRI images, the authors advocated the use of radial MRI images to more accurately assess for a cam deformity.

They further concluded that radiograph evaluation alone is not sufficient for the diagnosis of FAI, as it, and other modalities, lack the contrast resolution for characterization of soft tissue, compact bone, and cancellous bone.

Discussion

While there have been numerous studies focused on the best imaging modality for FAI, further investigation of each recommendation leads to determination of the next appropriate step in caring for a patient with atruamatic hip pain. The study by Clohisy et al. had its strengths: there was a meaningful sample size (85); there was a control group of asymptomatic, impingement-negative hips that were also matched for age; the study group had clinical signs and symptoms suggestive of impingement; and all measurements were performed in a standardized method. The authors concluded that the FL view was best for diagnosing FAI because it had the largest difference in alpha angle measurement between the control and impingement groups; however, this difference was only 1.2 degrees. A difference of only 1.2 degrees in the alpha angle measurement on radiographs is very small and not clinically relevant. The AP pelvis view produced the overall largest alpha angle measurement, with a mean measurement 6 degrees greater than the FL view. From this, one could argue that either the AP pelvic view overestimates the alpha angle, or the FL underestimates the alpha angle. The authors also conclude that the FL view radiograph is the most reliable radiographic method for diagnosing femoral head-neck abnormalities. While the FL view had an almost perfect interobserver agreement level of 0.83 when assessing the alpha angle, the AP pelvis view had a rating of 0.85. This small difference indicates that the AP pelvis view may be a more reliable measurement, and the authors conclusions were based on other non-objective measurements. Overall, both views studied produced mean alpha angle measurements that are considered consistent with cam deformity diagnosis, but the authors' conclusions about the FL view being a better choice versus the AP pelvic view are questionable.

The article written by Govsig et al. had strengths and weaknesses as well. Potential strengths include the large number of subjects (2800) and standardization of radiographs and measurements. However, when further analyzing the subjects, one realizes that while the mean age of the study population was less than 65 years old, and thus met inclusion criteria for this review, the mean age was 63.5 and included subjects up to 93 years of age. The degenerative changes that occur with aging in many patients due to multiple possible etiologies could certainly influence the applicability of the study results to a younger population. The authors concluded that cam deformities can be detected to an acceptable level on standardized AP pelvic radiographs avoiding rotation, and concurrent analysis of the triangular index increases the reliability. The mean alpha angle values used by the investigators in this study are below the accepted threshold for diagnosis of a cam deformity, which may indicate that many healthy hips were examined, and therefore contributing to the idea that the AP pelvis radiograph underestimates the alpha angle. This idea of underestimation by the authors led to the development of the triangular index. This measurement is based on the Pythagorean Theorem, making it a purely geometric measurement. According to the authors, this makes it less subjective versus the alpha angle measurement. This conclusion was drawn from data collected in the study, where interobserver agreement for the triangular index was found to be 0.95, compared to 0.83 for the alpha angle. However, this only demonstrates that radiologists made similar measurements of the triangular index. No data was presented on using the triangular index alone to diagnose cam deformities. There is data demonstrating that assessment of a pathological triangular index concurrently with an alpha angle measurement increases the number of subjects determined to have cam deformities, yet no cut-off diagnostic value for a pathologic triangular index was given. Further, to clinically use the triangular index also requires that the clinician assumes that most cam lesions occur at one specific location, at a point perpendicular to half the normal femoral head radius measured on a line through the center of the femoral neck. This measurement does not take into account that cam deformities can occur anywhere along the femoral head, though most frequently in the anterosuperior quadrant. If a deformity is not present at that perpendicular point, then the triangular index is not applicable. While it demonstrated great reliability in determining the hypotenuse (angle) value, the triangular index requires further research to determine acceptable thresholds to diagnose cam deformities. Its reliability in detecting cam deformities across the entire femoral head, in particular the anterosuperior quadrant, should also be examined. There is not currently enough evidence to use the triangular index clinically.

In studying the reliability of the beta angle, Brunner et al. conducted a very thorough study. Among its strengths were the presence of an asymptomatic control group; a large study population (100 subjects); and the standardized method of collecting images and measurements. Perhaps the study's greatest strength was the use of MRI as the standard of reference, as clinically this has long been accepted by surgeons and radiologists alike. The symptomatic group all had alpha angles greater than 55 degrees measured on MRI, which is the accepted diagnostic value of cam bony abnormality, and thus confirmed that these patients presented with cam-type FAI. The authors concluded that the presence of a small beta angle value on the beta view radiograph in a symptomatic patient may be sufficient evidence to diagnose cam-type FAI. While the authors indicate that a beta angle value less than or equal to 29 degrees had 100 percent specificity, an exact cut off value was never given. Additionally, when performed as recommended for radiographs, the patient positioning of 90/20/0 degrees of flexion, abduction, and rotation, respectively, may not show the full extent of a cam deformity (Pfirrman et al., 2006). As measurement of the beta angle had near-perfect inter and intraobserver reliability, and the process of determining the beta angle has low complexity, it may be a valuable clinical measurement in diagnosing FAI. However, more parameters for the analysis of each beta angle value and a reliable cut-off value is necessary prior to routine clinical use.

In studying the reliability of the FL view in screening for FAI, Konan et al. compared the alpha angle measurements in the FL view radiograph against alpha angle measurements determined on 3D-CT, which was used as the standard of reference. From this, the authors concluded that the FL view radiograph is not reliable in determining the alpha angle. The study's strengths were in the number of hips examined (n=32) and using 3D-CT as the standard of reference. The mean alpha angle measurements for both 3D-CT and FL view radiographs were both diagnostic of FAI. The FL view also produced "good" reliability as determined by the authors, with an interobserver reliability of 0.83. However, the authors concluded that the FL view was not reliable, and CT should be the imaging modality of choice. There is very little discussion as to how the authors arrived at this conclusion, and it is up to the reader to hypothesize about the reasoning. Perhaps the authors arrived at this conclusion because the FL view was said to overestimate the alpha angle in 18 cases and underestimate it in 14 cases. The reasoning may also have been because the agreement between the FL view radiograph and 3D-CT in determining the alpha angle was within five degrees in only about one-third (eleven) of the cases. When examining this, however, one must remember that 3D-CT was used as the standard of reference, not multiplanar MRI, which is considered the gold standard. It may be argued that the 3D-CT did not accurately assess the alpha angle. Also, alpha angles determined by the FL view had been previously demonstrated to produce measurements comparable to that of MRI (Clohisy et al., 2006). Had the authors further elaborated on their conclusion that the FL view radiograph was not reliable in determining the alpha angle, and if MRI had been used as the standard of reference, the validity of this study would have been increased. Clinicians should not discount the reliability of the FL view radiograph and also should not choose 3D-CT as the screening method of choice based on the results and analysis presented in is article.

The study by Barton et al. had very clear and well organized methods, adequate results, and clinically relevant reasoning to support the authors' conclusions. There was a large study group (68) and extensive statistical analysis to determine sensitivity, specificity, PPV, NPV, and accuracy for each of the three radiographic views. Perhaps its greatest strength was using axial oblique MRI as the standard of reference to compare alpha angle measurements in the three radiographic views. The use of the axial oblique (multiplanar) MRI was an interesting choice by the authors, as a prior article concluded that the axial oblique view does not appropriately visualize the anterosuperior femoral head quadrant and may underestimate the alpha angle (Rakhra et al., 2008). Forty-three of the 68 hips studied were FAI-positive based on an alpha angle measurement greater than 50.5 degrees. One may question if those determined to be FAI-negative may have occurred due to underestimation, and had the radial plane MRI been utilized, a greater number of the subjects would have been FAI-positive. Had this been the case, the results of the radiographic views would have produced lower reliabilities, and perhaps led to a different conclusion. However, the authors used the imaging modality that was and still is regarded as the gold standard in diagnosing FAI. Because of this, their results should be accepted as valid. However, their conclusion that radiographs in the Dunn position alone may be adequate to diagnose cam-type FAI should be further evaluated. As concluded by Domayer et al. (2010), MRI is an irreplaceable modality in imaging hips suspected of FAI, and it alone produces more accurate measurement than combinations of radiographs used together. From this study by Barton et al., clinicians can be assured that the Dunn position radiograph produces reliable alpha angle measurements, but should be wary in using it as the sole diagnostic tool in diagnosing cam deformities.

Beaule et al. (2005) concluded that 3D-CT is an accurate tool to assess for femoral head-neck asphericity. In their study, radiographs, multiplanar MRI, and 3D-CT were all utilized. There was a study group with clinically relevant signs and symptoms of FAI, and an asymptomatic control group. The difference in alpha angle measurements between these two groups was the basis for the authors' conclusion, yet needs further investigation. Radiographs were used to rule out acetabular pathology, MRI was used to assess chondral damage, and 3D-CT was used to make the alpha angle measurements. Rather than comparing the alpha angle measurement produced by the 3D-CT in the two groups against a standard of reference, the authors only compared the measurement between the two groups. While the symptomatic group had a greater mean alpha angle that is classically diagnostic of cam-type FAI, it can be argued that this measurement was overestimated. It would have been better evidence if the authors compared the 3D-CT alpha angle measurements against measurements determined with multiplanar MRI. The authors also state that an added benefit of the 3D-CT is its ability to quantify the degree of deformity for both the patient and surgeon. However, is this clinically relevant? A surgeon may be able to see the degree of deformity pre-operatively, but operatively, he will continue to perform osteoplasty until he is satisfied with the results. Clinicians should be cautious in using this study by Beaule et al. as grounds for using 3D-CT as their modality of choice in screening imaging for suspected FAI.

The study by Tannast et al. (2006) using the CT-based computer program HipMotion™ had strengths and weaknesses. The main strengths were the large number of hips studied (67) and the use of an asymptomatic control group to compare against the symptomatic study group. The results of the study demonstrate that symptomatic patients suspected to have FAI had decreased ROM in all planes. From this, the authors concluded that this method provides a reliable, accurate, and noninvasive tool for the assessment of hip impingement. It would have served the authors well to set a diagnostic value for each hip motion using the HipMotion™ system that was diagnostic for FAI. Simply demonstrating that symptomatic patients have decreased range of motion is not enough evidence to conclude that this modality is suitable for diagnosing FAI, as this is a widely known and accepted fact. Additionally, many other hip pathologies also produce limited range of motion. HipMotion™ is an advanced modality that may be of use in the future, but more research must be performed to set diagnostic values before clinicians utilize it to diagnose FAI.

Attempting to use a modality that is inexpensive, widely available, and does not incur a large radiation burden to diagnose cam deformities was the purpose of the study by Buck et al. (2010). The authors determined that ultrasound was a sensitive modality for the detection of an anterosuperior cam deformity. The data from the study supports this conclusion, but it also highlights the poor diagnostic performance of US in every other category, among which was the poor interobserver agreement on the measurement of the alpha angle. The authors imply that this should be used as a first-line modality in patients with hip pain before referral for radiographs. However, they also note that a positive test would require follow-up with radiographic imaging. If this is the case, why order such an ultrasound for symptomatic patients, as the suspicion for FAI would already be quite high based on taking a good history and performing an appropriate physical examination? Use of this modality would merely be a cost and time burden to the patient. Additionally, global visualization of the adult hip with US does not occur because adult bones are fully mineralized. Due to the poor reliability of objective measurements, the suggested radiographic follow up for a positive test, and the lack of global visualization of the adult skeleton, US should not be recommended for diagnosing cam deformities at this time.

Attempting to diagnose a cam deformity before the patient is symptomatic was a novel idea by Matar et al. (2008). The authors had a large study population (50) and used evidence based practice to diagnose the study group with cam-type FAI before performing SPECT, and the results of the study support their conclusion that if there is cartilage damage, a cam deformity is likely, even in the absence of symptoms. However, one must look at how practical the use of this modality is in the clinical realm. Rarely will a patient be referred for imaging when he or she is asymptomatic. Clinicians must also weigh the risks versus benefits of exposing an asymptomatic patient to the radiation burden incurred by this test. The authors do not discuss other SPECT findings that are indicative of FAI to suggest its use when a patient is symptomatic, and therefore the modality cannot be recommended as a diagnostic test for symptomatic patients. While it was a well-designed study that produced significant results, the use of SPECT in the clinical setting to diagnose FAI is not practical.

MRI is the gold standard for diagnosing FAI. Until the study by Rakhra et al. (2008), the oblique axial view was widely used; however, the author’s believe the oblique axial view underestimated the alpha angle and the radial view may be a better imaging option. In comparing symptomatic patients, the authors found a large difference in the mean alpha angle between the two views, with the radial images having a 17 degree greater mean alpha angle. Two conclusions can be drawn from this: either the radial plane is correct and the oblique axial view underestimates the alpha angle, or the radial plane overestimates the alpha angle and the oblique axial view is in fact more precise. The authors believe the former is the correct conclusion, and argue that 54% of the oblique axial images produced measurements less than 55 degrees. The authors further argue that radial imaging is preferred because it fully visualized the anterosuperior quadrant of the femoral head where many cam lesions occur, and data from their study supports this conclusion. Further research may be warranted to determine which MRI view is preferred. Rakhra et al. presented strong evidence for the use of the radial view; however, other studies have produced strong evidence for the oblique axial (multiplanar) view. All of these studies, however, have shown that MRI is a reliable option for the diagnosis of cam lesions and FAI.

The importance of imaging the symptomatic patient with MRI was reinforced in the study by Domayer et al. (2010). In the study, the researchers compared the alpha angle measurements of symptomatic patients determined on radiograph against radial view MRI. The study had a large sample size (60) and the authors used imaging methods that had already been proven reliable by other studies. Because the purpose of the study was to compare radiographs against MRI, the presence of an asymptomatic control group was not necessary. The authors increased the validity of the study by examining where the majority of cam deformities occur by using seven different imaging planes. They found that the majority of cam deformities occurred in the anterosuperior quadrant of the femoral head. Based on the findings by Rakhra et al. (2008), the authors used the appropriate MRI imaging plane, as the radial view is the best MRI plane to image this quadrant of the femoral head. While the Dunn view radiograph produced significant results, this study demonstrated why MRI is the gold standard in imaging suspected cam deformities.

When imaging a symptomatic patient with hip pain, there are strong, valid reasons for not choosing SPECT and US. SPECT should not be used because it is not clinically practical;

asymptomatic patients would not be referred for imaging. US should not be utilized primarily due to poor visualization of the adult human skeleton, as well as poor reliability in making objective measurements. Furthermore, it is suggested that a positive result from each of these modalities is followed up with more imaging, with radiographs, CT, and MRI all being recommended. Instead of placing an additional cost burden on the patient, the family practice PA should disregard SPECT and US as imaging choices.

The use of CT as the next step could be argued. Multiple studies have shown CT to be reliable in diagnosing cam deformities. CT offers the advantages of being less expensive than MRI. In the Midwest, an MRI of the hip ranges in price from $450 to $1050, compared to a CT of the hip that ranges in price from $240 to $530 (Change: Healthcare, 2011). Additionally, CT provides better visualization of the femoral head than radiographs. Beaule et al. (2005) argue that CT provides global visualization of the femoral head better than that of MRI. While the authors contend that MRI does not penetrate through the chondral tissue, multiple studies have provided excellent statistics on the accuracy of MRI (Domayer et al. 2010; Notzli et al., 2001; Rakhra et al., 2008). Either global visualization with MRI occurs more than Beaule et al. alluded to, or global visualization is not necessary to make the diagnosis. Beaule et al. also conclude that CT is able to quantify the deformity preoperatively, but how necessary is this? If a patient is referred for surgery, the actual visualization of the deformity would be better than a model recreated by a CT image. And while the computer model may indicate that a certain amount of bone will need to be shaved off, intraoperatively a skilled surgeon will use diagnostic testing, personal comfort levels, and past experiences, among other variables, to determine the extent of the osteoplasty. A positive CT will also almost always require follow up with MRI. Most surgeons would be hesitant to go directly to surgery based on a CT finding without first analyzing the soft tissue for chondral irregularities and/or labral tears with MRI. The radiation burden of CT must also be considered. The patient will incur a much greater radiation burden with CT (1000 millirems) than with radiographs (60 millirems) or MRI (no radiation) (American Nuclear Society, 2012). When weighing the pros and cons of CT, it becomes clear that it should not be the initial diagnostic imaging modality chosen by the family practice PA in screening and initially evaluating a symptomatic patient.

Radiographs have been demonstrated to provide accurate diagnosis of FAI and cam deformities. They can be used to rule out or rule in other diagnoses that are part of the clinician's differential diagnosis, and they are the least costly modality, which is important in today's healthcare system and when considering the increasing prevalence of the disorder. When assessing the use of radiographs as the imaging modality to screen for FAI, two other questions must be answered: which radiographic view(s) should be used, and which objective measurement should be taken? Furthermore, the clinician must have the ability to quickly and accurately determine the different measuring methods. There is evidence for the use of the AP pelvic, FL, and Dunn views, as well as for the alpha angle, beta angle, and triangular index. With all these measurements and views to analyze, it can be difficult for the clinician quickly and accurately select the appropriate options. The follow up of radiographs must also be considered. If a radiograph is found to be negative for a cam deformity in a symptomatic patient, the patient is treated conservatively until symptoms resolve, or an MRI is ordered. If a radiograph is found to be positive in a symptomatic patient, a follow up MRI is typically ordered to assess soft tissue pathology. Though radiographs are relatively inexpensive compared to other imaging modalities, a subsequent MRI occurs in most symptomatic cases anyway. Therefore, radiographs should not be the initial diagnostic imaging modality when deciding the next step in a young symptomatic patient, as they place an unnecessary cost, time, and radiation burden on the patient.

Considering all of the information analyzed through the present literature review, MRI is the best screening imaging modality for young, active patients with new onset hip pain for FAI. In the case of Mr. H, the patient presents with many of the cardinal signs of cam-type FAI, including groin pain that is not alleviated with rest, is becoming constant, and is associated with clicking in the joint. Furthermore, on physical exam, Mr. H had decreased internal rotation with the hip flexed to 90 degrees, as well as a positive impingement sign. A radiograph series could be ordered to rule in/out multiple causes of his hip pain; however, in this instance, this would not be the best practice. Here, ordering an MRI for Mr. H offers many advantages over a radiograph series. A key benefit of MRI is that the precise positioning of the patient is not critical in obtaining accurate results. While there is debate as to which view to use in diagnosing cam-type FAI, multiple views are captured during the imaging test. Although the oblique axial view may be the most commonly used, the research by Rakhra et al. (2008) and Domayer et al. (2010) suggest the radial view is best. Either way, results with good sensitivity and specificity will still be obtained. Additionally, MRI offers multiple advantages over CT and radiographs. Unlike CT and radiographs, MRI is able to concurrently assess soft tissue pathology while assessing bony abnormalities, so further follow up of a positive screening test is not warranted. Additionally, MRI has the advantage of no radiation exposure. The cost of MRI may be its greatest pitfall in being the first-line imaging modality, as the average cost of imaging the hip with MRI, radiographs, and CT is $1400, $380, and $925, respectively (New Choice Health, 2012). Yet, it must be considered that when referring a patient for either radiographs or CT first, further follow-up by MRI is commonly warranted, so the initial imaging was an unnecessary cost.

Imaging of patients with embedded metal must also be considered, as this is an absolute contraindication of MRI. In this instance, the Dunn view radiograph or CT may be warranted as first-line imaging. When evaluating all studies, it is evident that the family practice PA should refer the symptomatic patient for MRI as the next step in the diagnostic process.

Conclusion

FAI has become an increasingly recognized cause of atraumatic hip pain. When a young adult patient presents with hip pain, especially with complaints of deep pain in the groin, the family practice PA must place FAI high in the differential diagnosis. In a patient who presents with the above complaints, a thorough history and physical exam must be gathered. The clinician must recognize the most common signs and symptoms of FAI and be comfortable ordering the appropriate diagnostic imaging, initiating conservative treatment, and/or referring appropriately. A patient presenting with deep groin pain and increased pain with activity, but no reports of clicking or catching in the joint, and has a negative impingement sign is an appropriate candidate for standard radiographic imaging of the hip. If the results are negative or inconclusive for a disorder, conservative treatment should be initiated. This may include any or all of the following: cessation of the offending activity(s), heat, ice, over-the-counter analgesics, and physical therapy. A follow-up appointment should be scheduled in six to eight weeks. If the patient continues to complain of groin pain, yet denies clicking/catching in the joint and still has a negative impingement test on physical examination, referral to a sports medicine or orthopedic specialist is warranted.

A patient presenting similar to Mr. H, with complaints of deep groin pain that is not alleviated with rest, experiences clicking in the joint, and has limited or painful passive internal rotation with the hip flexed 90 degrees, as well as a positive impingement sign should have an MRI ordered as the initial diagnostic modality. MRI provides superior imaging of the anterosuperior quadrant of the femoral head where most cam lesions occur compared to the Dunn view radiograph. MRI also offers the benefit of concurrently imaging the labrum and intrarticular cartilage. To better identify soft tissue pathology, an MRA could be ordered;

however, for the diagnosis of FAI alone, MRI without contrast is highly acceptable and superior to all other imaging modalities discussed.

It can be argued that MRI is too costly as a first-line modality and that insurance companies may not cover its expense in this instance. Yet, when this is examined further, it can be seen why using MRI as the first-line modality is a better evidence-based practice. When a patient reports clicking/catching in the hip and/or has a positive impingement sign, there is a high suspicion for FAI, labral, and articular cartilage pathology. Standard hip radiograph views have not been shown to be advantageous in evaluating such patients for FAI, especially when considering that radiographs will not assist in evaluating for soft tissue or mild articular cartilage pathology. Patients receiving radiograph views of their hip who are at high suspicion for FAI or soft tissue pathology would still be referred for an MRI, meaning the radiograph was a time and cost burden, as well as injudicious use of medical resources. In some instances, such as the one described above, obtaining an MRI first and disregarding the radiograph would be more cost-effective and overall better medicine.

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Tables

Barton, Salineros, Rakhra, Beaule (2010)	
Modality	-Radiographs compared to MRI measurements
Demographics	-N = 68 -Mean age 38 -43 with known cam deformity -25 with labral tears
Results	-Highest sensitivity, specificity, PPV, NPV, and accuracy compared to crosstable lateral and AP views
Implications	-Dunn view is highly representative of MRI measurements of the alpha angle -Use of Dunn view radiograph alone may be adequate for evaluation of FAI
Clinical Application	-The alpha angle measurements demonstrate that the Dunn view is valid and should be the position of choice for radiographs -However, study by Domayer et al. suggested that MRI alone is better than radiographs, even when a combination of radiographs is used -Therefore, clinician should be wary in using radiographs alone in diagnosis of FAI

Beaule, Zaragoza, Motamedi, Copelan, Dorey(2005)	
Modality	-CT
Demographics	-N = 36 -Mean age 40.7 -Pts had 3 months persistent pain with minimal response to conservative therapy
Results	-Alpha angle 66.4 vs. 43.8 -Beta angle 40.2 vs. 43.8 -(+) FAI on alpha angle 26/36 -Alpha/beta ratio (+) FAI was 29/36 -Relaibility 0.6(moderate)
Implications	-CT is accurate tool to diagnose FAI -Can also quantify amount of deformity preoperatively as added assistance to surgeon
Clinical Application	-Alpha angle only compared between 2 groups, not between modalities; CT never compared against MRI -Is quantifying the amount of deformity necessary? Surgeon will perform osteoplasty until satisfied -Clinicians should be careful to use CT based on this research

Brunner, Hamers, Fitze, Herzog (2010)	
Modality	-Radiograph -Beta angle
Demographics	-N = 100 -Sx mean age 34.8, n = 50 -Asx mean age 39.3, n=50 -MRA to measure alpha angle -Radiograph to measure beta angle
Results	-Beta angle mean: sx = 15.6, asx = 38.7 ($p<.001$) -Interrater 0.89/0.85 (sx/asx) -Intrarater 0.82/0.89 (sx/asx)
Implications	-In symptomatic patients positioned as described, beta angle on radiograph is sufficient to diagnose FAI -Cost effective alternative to MRI
Clinical Application	-Position recommended may not fully visualize anterosuperior (AS) quadrant -No cut-off value for diagnosis of FAI -Good idea with good results, but more parameters and a cut-off value required before being recommended first-line imaging

Buck, Hodler, Zanetti, Dora, Pfirrman (2010)	
Modality	-Ultrasound (US)
Demographics	-N = 50 -Mean age 39 -All had sxs suggestive of FAI
Results	-Mean alpha angle 64.8 vs. 57.1 between readers 1 and 2 in anterior quadrant -69.5 vs 72.7 in anterosuperior (AS) -Poor agreement with values determined on MRA -91% avg. sensitivity for FAI in anterosuperior quadrant
Implications	-US sensitive for detection of cam deformity in AS quadrant -Offers pros of no radiation exposure, fast, cost-effective -Can be used as first line to rule out FAI in symptomatic patients
Clinical Application	-Poor diagnostic quality in every other category -Cannot fully visualize adult skeleton due to full mineralization -Positive would still require f/u, so it was a waste of time -US should not be used as first-line imaging

Clohisy, Nunley, Otto, Schoenecker (2006)	
Modality	-Radiograph
Demographics	-N = 61 -Mean age 32 YO -Symptomatic group compared against asymptomatic group
Results	-Alpha angle significantly larger in symptomatic group on AP, crosstable, and Frog-Leg views -Frog leg view had largest difference between asx and sx groups -AP had better interobserve agreement than FL (.85 vs. .83)
Implications	-FL most reliable to determine alpha angle -Alpha angle most useful measurement to determine femoral head asphericity -FL view should be used for detection of FAI because is most reliable, inexpensive, easy, and effective
Clinical Application	-Though authors conclude FL is most reliable, AP demonstrated higher reliability. -Conclusion made on FL having largest difference between asx and sx groups -But AP had largest mean angle value -Clinicians should be wary to use FL radiograph based on this study

Domayer, Chan, Bixby, Mamisch, Kim (2010)	
Modality	-MRI -Compares MRI vs. radiograph
Demographics	-N = 60 -Mean age 28 -All with clinical evidence of FAI
Results	-Radial MRI diagnosed 45/60 -AP 26/60 -Crosstable/Dunn 35/60 -Radiograph combo 40/45 -Overall, Dunn had greatest sensitivity/specificity of radiographs
Implications	-Radial MRI should be first line: images AS quadrant the best -MRI alone is more sensitive than Dunn view, or combo of radiographic views -Dunn is best radiograph view overall
Clinical Application	-Authors used evidence from Rakhra study -Can argue again that radial MRI overestimated, and therefore results are skewed -However, study demonstrates that MRI should be first-line modality and is superior to radiographs -Would like to see MRI vs. CT in known cases that went to surgery

Gosvig, Jacobsen, Palm, Sonne-Holm, Magnusson (2007)	
Modality	-Radiograph -Triangular index
Demographics	-N = 2800 - Mean age 63.5 YO -AP radiographs while weight bearing
Results	-Mean alpha angle men 54.2 -Mean alpha angle women 45 -Triangular index > 2 mm closely related to alpha angles greater than 55 degrees (p<.001)
Implications	-Cam deformities can be detected using AP radiographs without femoral rotation -Concurrent assessment with Triangular Index makes AP sufficient to diagnose FAI
Clinical Application	-Mean alpha angles were below threshold of 55 degrees for FAI diagnosis -Triangular index was not studied alone to determine reliability in diagnosing FAI/cam deformities -Value of 2 mm correlated with positive cam deformities, but no cut-off value established -Only looks at 1 area of femoral head and does not visualize anterosuperior quadrant where majority of deformities occur. -Not enough evidence to currently use TI or TI on AP film

Konan, Rayan, Haddad (2010)	
Modality	-Radiograph -Evaluation of Frog Leg view
Demographics	-N = 32 -Mean age 32 YO -Alpha angle on FL compared to standard of reference on CT
Results	-Mean alpha CT 65.11 -Mean alpha FL 58.71 -Overestimated in 18, underestimated in 14 -Reliability 0.83
Implications	-FL is inexpensive but not accurate -CT scans are essential for pre and post op examination of FAI
Clinical Application	-3DCT was used as reference, not MRI; perhaps CT overestimated -FL had interobserver reliability of 0.83, but concluded to be unreliable, yet no discussion for this conclusion -Clohisy had previously demonstrated value of FL -Clinicians should not conclude to use CT based on information provided

Matar, May, Raymond, Beaule (2008)	
Modality	- SPECT
Demographics	-N = 50 -Mean age 33.9
Results	-Sensitivity 84.7 -22/26 known cases of FAI detected by SPECT
Implications	-(+) SPECT can be early indicator of FAI -Sensitive test for imaging possible FAI
Clinical Application	-Nice theory; however, will not clinically see asx patients to refer them for SPECT -Large radiation burden for a test in which a positive test would require further imaging -Overall, is not practical in the clinical setting for the dx of FAI

Rakhra, Sheikh, Allen, Beaule (2008)	
Modality	-MRI -Radial imaging vs. multiplanar
Demographics	-N = 41 -Mean age 39
Results	-Alpha angles 53.4 vs 70.5 multiplanar vs. radial -Maximum deformities in anterosuperior quadrant
Implications	-Radial MRI should be first-line imaging over multiplanar: multiplanar underestimates deformity in AS quadrant -Radiographic evaluation alone is not sufficient -MRI offers benefits of soft tissue, compact, and cancellous bone imaging that is not seen with other modalities
Clinical Application	-Authors correct in assessment of MRI as superior in its multiple abilities -Can argue that radial overestimated angle; multiplanar has been proven to be great in many other studies and is often the standard of reference -More research required to determine best MRI view, but study reinforces notion that MRI is reliable for diagnosis of FAI

Tannast, Langer, Langlotz, Puls, Murphy, Siebenrock (2007)	
Modality	-HipMotion system
Demographics	-N = 67 -Sx vs. asx
Results	-ROM was decreased in flexion, IR, abduction with excellent interclass correlation coefficient -No difference in ROM with extension, adduction, or ER
Implications	 -HipMotion reliable tool for diagnosis of hip impingement based on lack of ROM
Clinical Application	-Study demonstrates that sx patients have a decreased ROM in the planes that close the joint space; this is already known -Many other pathologies can also cause this -No cut-off values established for diagnosis of FAI in the statistically significant planes -At this time, this modality should not be used to diagnose FAI

Definitions

Alpha angle: the objective measurement made by radiologists on MRI, CT, and radiographs to diagnose a cam deformity, and thus FAI. It is determined by drawing a best-fit circle over the femoral head and determining the center of the femoral head. One arm of the angle is drawn from the center of the femoral head through the axis of the femoral neck at its narrowest point. The other arm is drawn from the center of the femoral head through the point on the peripheral femoral rim that exceeds the boundary of the best-fit circle, representing the osseous abnormality. A measurement greater than 55 degrees is universally accepted as the cut-off value for diagnosing a cam deformity, although some authors use a measurement greater than 50.5 degrees as diagnostic for a cam deformity.

Beta angle: an objective, radiographic measurement of the distance between the pathological femoral head-neck junction and the acetabular rim with the hip in 90 degrees of flexion. A smaller beta angle measurement is consistent with the diagnosis of a cam deformity, although no diagnostic cut-off values have been established.

Cam-type FAI: a subset of FAI that most commonly occurs in younger, active males who are subjected to repetitive hip flexion and adduction. It is characterized by a cam deformity, which is an osseous overgrowth of the femoral head, neck, or head-neck junction. The exostosis typically occurs in the anterolateral quadrant of the femoral head, although it may occur in any quadrant.

Impingement Test: a special test of the hip that a clinician performs within the physical exam. The clinician passively flexes, adducts, and internally rotates the patient's hip and notes clicking/catching in the joint, or complaints of pain by the patient. The clinician then extends the hip and knee to full extension, and passively flexes, adducts, and externally rotates the patient's hip, again assessing for clicking, catching, or complaints of pain, all of which indicate a positive test. Clinicians should be suspicious of intraarticular pathology, as well as FAI with a positive impingement test.

Femoroacetabular Impingement (FAI): a condition of the hip related to chronic, repetitive motion. The classic presentation of FAI is hip/groin pain with increasing severity, complaints of clicking or catching in the hip joint, and limited hip flexion and internal rotation. When left undetected, FAI can lead to the formation of paralabral cysts, acetabular labral tears, and damage to the intraarticular cartilage. Chronic FAI can also subject the patient to early-onset osteoarthritis of the hip.

Mixed-type FAI: the most common form of FAI that presents as both acetabular overcoverage of the femoral head and an osseous abnormality of the femoral head, neck, or head-neck junction.

Pincer-type FAI: a subset of FAI that most commonly occurs in middle-aged females. This type of FAI is characterized by an overgrowth of the posterior rim of the acetabulum. This type of osseous abnormality can lead to chronic shearing of the intraarticular cartilage, leading to scarring and ossification, which further contributes to the acetabular overcoverage.

Triangular index: an objective, radiographic measurement of femoral head asphericity. It is determined by finding the center of the femoral head; drawing an axis though the center of the femoral shaft, and making two arms of a right triangle. The first arm is measured at a distance equal to half the radius of the femoral head. The second arm is drawn through the point of maximal deformity on the femoral head periphery. The lengths of these two arms are determined, and using the Pythagorean Theorem, the length of the hypotenuse is determined. If the hypotenuse length exceeds the radial length by 2 mm, this is considered indicative of a cam deformity.

Abstract

Objective: Determine the evidence-based screening modality of choice in young, active patients with new onset hip pain for femoroacetabular impingement (FAI). **Method:** Inclusion and exclusion criteria were established for a clinical review article and PubMed was searched. Of 311 possible articles, 11 met criteria and were evaluated. **Results:** Multiple modalities including standard radiograph, CT scan, MRI, ultrasound and bone scan have been evaluated as screening modalities for FAI. Virtually all of the studies had limitations and few have been validated. **Conclusion:** When evaluating patient cost, clinical application and patient care, MRI is the best modality to evaluate for FAI in a young, active patient with multiple features compatible with the disorder.